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MEASURED PERFORMANCE OF FIVE MIST ELIMINATOR MODULES CONSIDERED FOR THE SCRUBBERS INSTALLED AT THE INTERMOUNTAIN GENERATING STATION, UNITS 1 AND 2

Intermountain Power Agency Agreement No. 330
Task IGS-2 Determination of Mist Eliminator Performance

DynaGen, Inc. Project No. IPP-3
DynaGen, Inc. Report No. 2528

Submitted to:

Intermountain Power Facilities
P.O. Box 111, Room 667
Los Angeles, CA 90051-0100

Attention:

Mr. David Clark

Prepared by:

Gerald B. Gilbert
Lewis A. Maroti

January 24, 1994

Submitted by:

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Section 1

OBJECTIVES AND TEST CONDITIONS FOR MIST ELIMINATOR TESTS

As part of a program to eliminate stack gas reheaters and operate the absorber outlet ducts and stack with saturated gas flow, the mist eliminators will be changed to more efficient modules. The test program described in this report, compares the performance of the existing ME module and four other modules that are being considered as replacements.

The objective of the test program was to measure the pressure loss and carryover performance of the five mist eliminator modules supplied to us. The following information was measured:

(1) pressure loss versus face velocity for each liquid loading level and for dry gas flow;

(2) breakthrough velocity for each liquid loading level; and

(3) approximate percent carryover (Q_{CO}/Q_L x 100) for each wet test point.

The test program included four combinations of liquid loading and droplet size, each tested at five face velocity values as identified in the test matrix below. Tests 2 and 3 where the liquid loading is 1.6 and 2.57 gpm/ft^2 respectively are more representative of washing rates where as the Tests 1 and 4 are more representative of absorber spray carryover.

Test No.	Liquid Loading	Gas Velocity at Mist Eliminators, ft/min. 600	700	800	900	1000
1	Droplet dia. = 800-3,000 μm $(Q/A)_{LIQUID}$ (gpm/ft^2) $(Q/A)_{LIQUID}/Q_{GAS}$ (grains/ft^3)	 .55 53	 .55 46	 .55 40	 .55 36	 .55 32
2	Droplet dia. = 800-3,000 μm $(Q/A)_{LIQUID}$ (gpm/ft^2) $(Q/A)_{LIQUID}/Q_{GAS}$ (grains/ft^3)	 1.60 156	 1.60 134	 1.60 117	 1.60 104	 1.60 94
3	Droplet dia. = 800-3,000 μm $(Q/A)_{LIQUID}$ (gpm/ft^2) $(Q/A)_{LIQUID}/Q_{GAS}$ (grains/ft^3)	 2.57 250	 2.57 215	 2.57 188	 2.57 167	 2.57 150
4	Droplet dia. = 30 μm $(Q/A)_{LIQUID}$ (gpm/ft^2) $(Q/A)_{LIQUID}/Q_{GAS}$ (grains/ft^3)	 .065 6.3	 .065 5.4	 .065 4.7	 .065 4.2	 .065 3.8

The results to be transmitted are:

- Summary of test procedure and results;
- Liquid carryover at all test points; and
- Pressure drop for all test conditions specified above and for dry operation at each flow point.

Section 2

EXPERIMENTAL TEST SYSTEM

The DynaGen mist eliminator test rig described in this section is an open loop test system that draws unsaturated air from the laboratory through the mist eliminator test module and test system. It was designed to determine breakthrough velocity by observation and to measure the amount of liquid carryover at velocities above breakthrough velocity.

2.1 Test System Construction and Geometry

A sketch of the mist eliminator test rig used for all testing is shown in Figure 2-1 and a picture is shown on Figure 2-2. They show the following features:

- the air inlet duct measures 24 inches by 36 inches in the horizontal direction;
- the vertical face velocity of the air can be adjusted from 0 to 1,500 fpm;
- the air inlet duct extends 30 inches below the inlet face of the mist eliminator;
- flow through the test module discharges to a flow area of 40 inches by 52 inches. This provides an 8 inch trough around the perimeter of the test module. Liquid that is carried through the test module collects in the trough or in the laboratory mist eliminator and is prevented from draining downward along the side walls back into the test module;
- liquid separated by the test module is collected in Tank 1;
- liquid carried through the test module is collected in Tank 2; and
- the mist eliminator module is encased and sealed to prevent liquid from bypassing active channels. The modules were acid etched for 2 hours in a 0.2 molar solution of sulfuric acid to make the surface wetting performance similar to field service conditions.

An array of six nozzles (two rows of three nozzles) supply water spray onto the inlet face of the test module for Tests 1, 2, and 3. For Test 4, two aerosol generators were installed in two opposite corners of the inlet duct bellmouth. Air flow is drawn through the mist eliminator and test rig by a large laboratory blower.

2.2 Instrumentation

A list of nomenclature used in this section and throughout the report is given in Table 2-1. Instrumentation used for test measurements includes:

- ASME standard orifice to measure the volume rate of gas flow (Qg);

- static pressure wall taps located at two elevations: P_{S1} (16 inches upstream of the inlet face of the test module); P_{S2} (15-1/2 inches downstream of the inlet face of the test module (Figure 2-1)). At P_{S1}, there is one static tap on the rear wall, equidistant from the side walls. At P_{S2} there are four taps, one on each wall. The wall taps are connected to an inclined tube manometer (6 inches of water maximum) to measure gas flow static pressure;

- a gate valve and 0 to 15 psig pressure gage to control and measure liquid flow rate supplied to the calibrated nozzles for the three largest flow rates (Figure 2-1);

- liquid collected by the test module is caught in Tank 1 (Figure 2-1). The liquid volume flow rate is determined by measuring the time elapsed to fill a known volume of the tank, using a stopwatch and scale;

- liquid carried through the test module is collected in Tank 2. The liquid volume flow rate is measured with a graduated cylinder and a stopwatch. Q_{T2} and Q_{ME} can be measured separately; and

- the flow rate of liquid that evaporates between the nozzle discharge and laboratory mist eliminator is determined by measuring the wet bulb temperature and dry bulb temperature of the gas at those two locations. This quantity was found to be insignificant for Tests 1, 2, and 3 - less than 3 percent of the nozzle flow rate. For Test 4, the evaporation is significant, accounting for up to 36 percent of aerosol generator flow rate where droplets are very small and gas flow is large.

2.3 Test Procedure

The gas flow and water flow conditions for a test point are set on the model and sufficient time is allowed for equilibrium of water drainage rates to be reached. All of the test data is then recorded with duplicate measurements taken for all water flow rates to insure accuracy and equilibrium. Carryover observations are made at each set flow condition to determine the liquid breakthrough velocity range.

Mist Eliminator Test System
With Instrumentation

Note: Nomenclature on Table 1

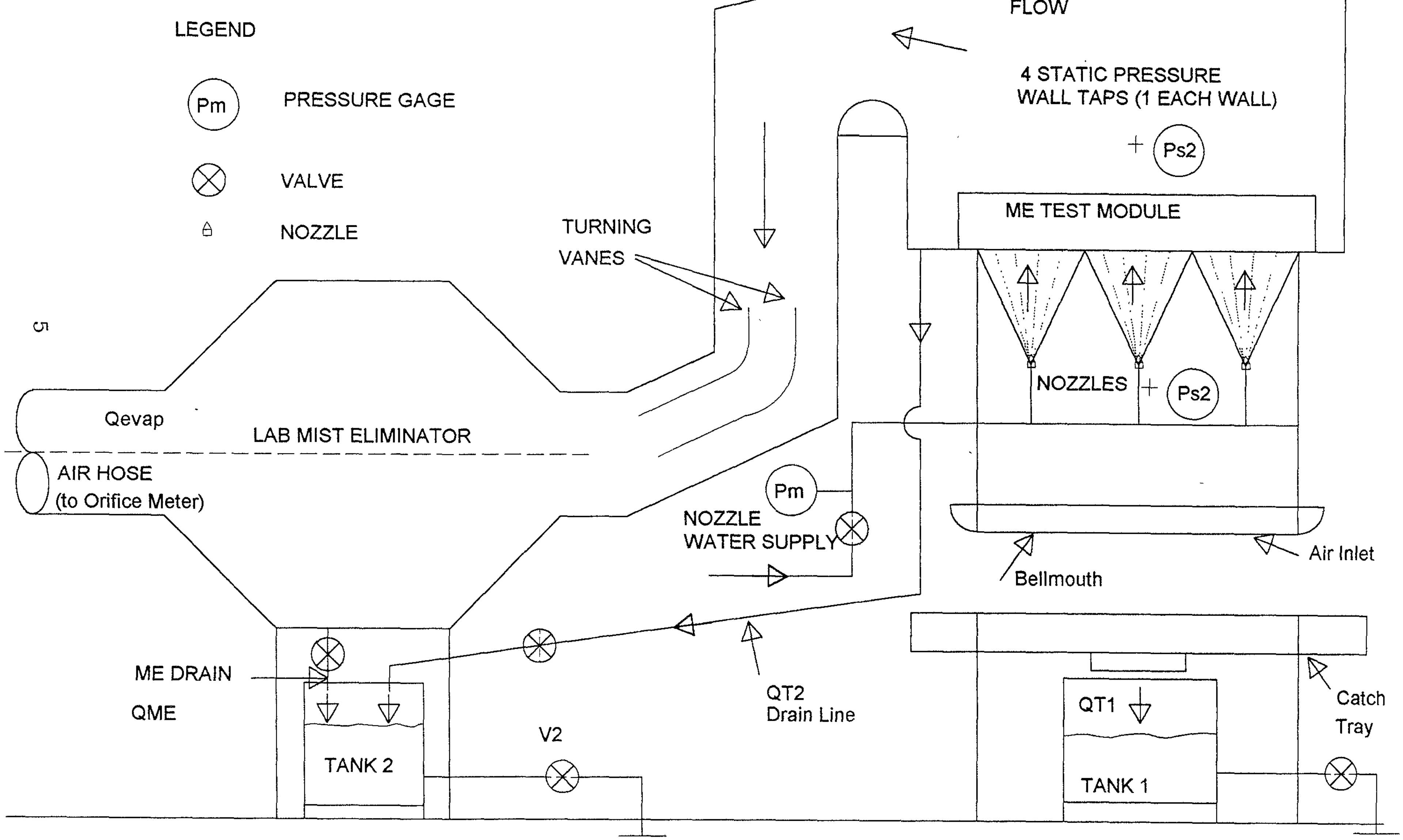

Figure 2-2 Picture of DynaGen Mist Eliminator Test System

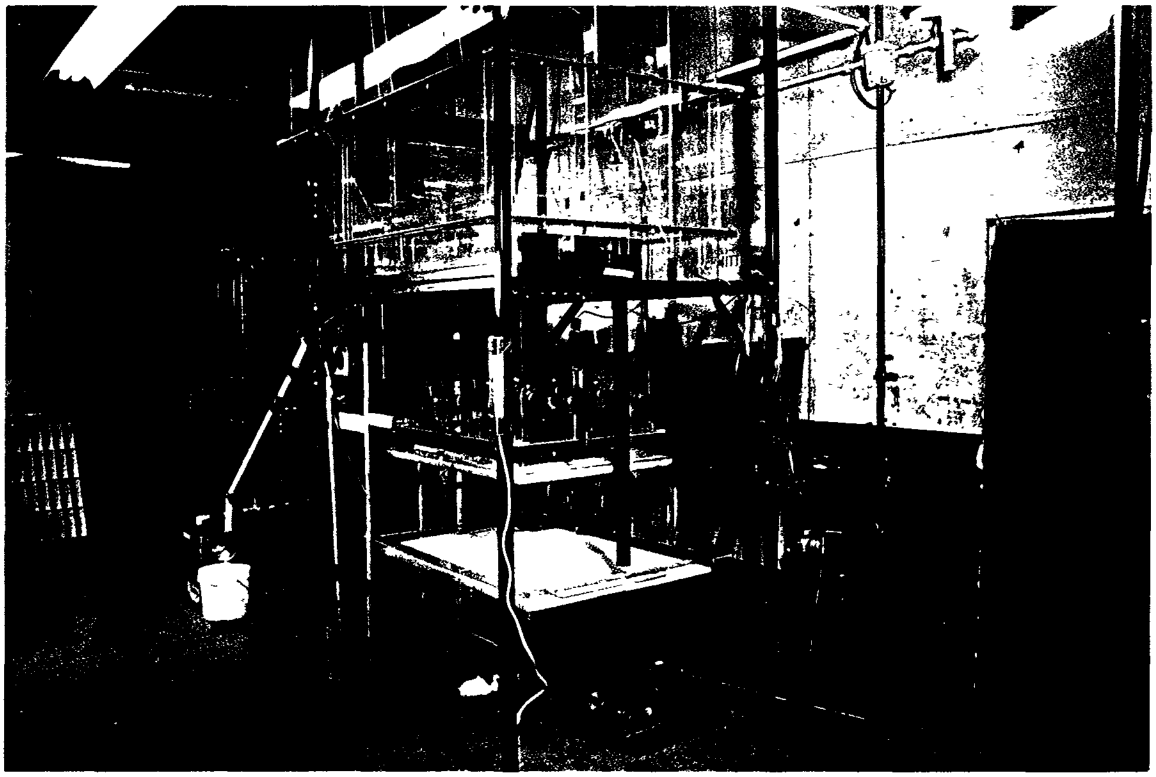

Table 2-1

NOMENCLATURE LIST

Parameter	Units	Definition
A	ft^2	Area of Mist Eliminator Module Face Exposed to Inlet Gas Flow
Q_g	acfm	Gas Volume Flow Rate
V_g	ft/min	Gas Velocity = Q_g/A at Mist Eliminator Inlet
V_{BT}	ft/min	Gas Velocity at Which Liquid is First Seen at Mist Eliminator Discharge
ΔP	in·H_2O	Total Pressure Drop Across Mist Eliminator Module
Q_N	gpm	Liquid Flow Rate Provided by Nozzles
Q_{T1}	gpm	Liquid Flow Rate Collected Under Mist Eliminator Module
Q_{T2}	gpm	Liquid Flow Rate Collected Downstream of Mist Eliminator Module on Ledge
Q_{ME}	gpm	Liquid Collected By Laboratory Mist Eliminator
Q_{EVAP}	gpm	Liquid Flow Rate Evaporated From Nozzle Discharge to Laboratory Mist Eliminator Outlet
Q_{CO}	gpm	$Q_{T2} + Q_{ME} + Q_{EVAP}$
Q_N/A	gpm/ft^2	Liquid Load = Liquid Flow Rate Impinging on Mist Eliminator Module Inlet Face, Dividing by Face Area
Q_{TOT}	gpm	$Q_{T1} + Q_{CO}$
Q_{CO}/Q_{TOT}	%	Liquid Carryover Ratio
ρ_g	lbm/ft^3	Gas Density at Mist Eliminator Module Inlet
P_{S1}	in·H_2O	Wall Static Pressure Below ME Inlet
P_{S2}	in·H_2O	Wall Static Pressure Above ME Outlet

Section 3

GEOMETRY AND TEST RESULTS FOR MIST ELIMINATOR MODULES

3.1 Discussion of Carryover Measurements

There are three components of the total liquid carryover which are defined on Table 2-1:

(1) Q_{T2} is liquid carryover from the test module collected on the 8" ledge around the outlet of the ME. This liquid is collected and is not allowed to drain back through the mist eliminator passages or to drain down the wall bypassing the ME. All of this liquid may not be test module carryover in an absorber installation since some large droplets could fall back into the ME and drain downward.

(2) Q_{ME} is liquid carryover from the test module collected by the final laboratory high efficiency mist eliminator. All of this liquid is test module carryover.

(3) Q_{EVAP} is liquid that evaporates into the unsaturated air stream between the inlet spray location beneath the test module and the outlet of the high efficiency laboratory mist eliminator. Most of this evaporation takes place downstream of the test module and should be counted as carryover. Since our test system was designed to evaluate carryover at gas velocities above the breakthrough velocity there was no need to construct a more expensive closed loop system where saturated gas flow could be used. For the tests on this project, the evaporation represents 100% of the carryover for some of the modules at the lower face velocity levels.

The tests for the five mist eliminator modules presented in the following subsections were all tested in the same way and the carryover data represents the sum of these three components. The test data table for each mist eliminator test module presents values for each of the three components when they were large enough to measure. The passage geometry of the four new mist eliminator modules tested at DynaGen is presented on Figure 3-1. Subsections 3.2 through 3.6 discuss each mist eliminator separately. Section 4.1 compares the results from the five mist eliminator modules.

3.2 Existing Field Mist Eliminator Module

Figure 3-2 shows pictures of two existing field mist eliminator modules. The blue module was sent directly from the plant but it was slightly damaged when it arrived. The lower module was a module of the same geometry which we had in our laboratory. Since the module we had was undamaged and was ready to be tested, we selected the lower module on Figure 3-2 for the test series reported in this subsection.

The open blade mist eliminator designs of this type are more susceptible to reentrainment of liquid inside the module and generally have lower breakthrough gas velocities.

As shown on key Table 3-1, the test results for pressure loss are presented in graphical form on Figure 3-3 and the liquid carryover results are presented in tabular form on Table 3-2 and in graphical form on Figures 3-4 and 3-5.

Table 3-2 shows that all but two of the 17 tests run had a measurable liquid carryover other than evaporation. The three tests in the test matrix not conduct were left out because carryover was already above 30% for the highest gas velocity tested in the same series. Large droplet reentrainment carryover was visible at 700 fpm and was judged to start in the range of 650 to 700 fpm. Carryover amount increases rapidly above the breakthrough velocity for all inlet liquid loads as shown on Figures 3-4 and 3-5 as well as Table 3-2.

The pressure loss curves on Figure 3-3 are closely grouped together where each curve represents results for a different liquid loading. The symbol legend is in the upper left corner of the figure. The dry results are the lowest curve and the pressure loss increases a small amount for each increase in liquid loading.

3.3 Munters T-271 Module

Figure 3-1 specifies the geometry and Figure 3-6 shows a picture of the Munters T-271 module tested.

The closely spaced blades (0.875") promote droplet deposition and the angled surface grooves promote good drainage to the partition walls.

As shown on key Table 3-1, the test results for pressure loss are presented in graphical form on Figure 3-7 and the liquid carryover results are presented in tabular form on Table 3-3 and in graphical form on Figures 3-8 and 3-9.

Table 3-3 shows that the 600 fpm and 700 fpm tests for all liquid loadings have only an evaporation component (Q_{EVAP}) to the total liquid carryover and no large droplet carryover. As shown on Figures 3-8 and 3-9 large droplet reentrainment and breakthrough begins at gas velocities between 700 and 800 fpm. Above 800 fpm for Tests 1, 2, and 3 with large droplet inlet loading of 0.55 gpm/ft^2 or greater, the liquid reentrainment carryover increases rapidly with gas velocity increase. Many of the reentrained droplets appear to be large (about 3/16" diameter) as can be seen on the video provided. The droplets appear to originate at the last bend corner.

The pressure loss curves on Figure 3-7 for dry gas flow and four liquid loadings are spread significantly apart particularly at gas velocities above 800 fpm. This shows a significant sensitivity of pressure loss due to liquid in the mist eliminator passages. Even a small liquid loading of 0.071 gpm/ft^2 (Test 4) increases the pressure loss significantly above a dry condition.

3.4 Munters T-272 Module

Figure 3-1 specifies the geometry and Figure 3-10 shows a picture of the Munters T-272 module tested.

The mist eliminator blades of the T-272 module are the same geometry as the T-271 module but they are spaced twice as far apart (1.75"). This increases the amount of liquid carryover at low velocities but decreases the amount of carryover at high velocities as compared to the T-271 module. This characteristic makes the T-272 module better for first stage mist elimination where liquid loadings are higher and the wider passage width makes cleaning of the ME passages easier.

As shown on key Table 3-1, the test results for pressure loss are presented in graphical form on Figure 3-11 and the liquid carryover results are presented in tabular form on Table 3-4 and in graphical form on Figures 3-12 and 3-13.

Table 3-4 shows that for the high inlet liquid loading tests numbers 2 and 3 there is measurable carryover in liquid form even at 600 fpm. Visual observation shows breakthrough of some large droplets in the 600 to 700 fpm range. The frequency of droplets increases as gas velocity increases and above 800 fpm and the measured carryover increases rapidly. The droplets appear to originate at the last bend corner. For the high inlet loading Test 3, the attempted measurement of Q_{ME} was inconsistent so all liquid carryover was shown as Q_{T2} ledge carryover where as in reality there is some carryover coming from the laboratory mist eliminator as for Tests 1 and 2.

The pressure loss curves on Figure 3-11 are fairly close together and much lower than the T-271 curves. This is the effect of the wider passage dimension (1.75") which makes the passage more open and less sensitive to the presence of water in the passages.

3.5 Koch V111-3-1.5 Module (B-800)

The only designation given to us on this module was B-800 marked on the mist eliminator. We believe that this module is also designated as V111-3-1.5. The geometry of this mist eliminator is specified on Figure 3-1 and a picture is shown on Figure 3-14.

The blade spacing is 1.35 inches between blades and 1.5 inches between blade centerlines. This is about halfway between the spacing of the two Munters modules (T-271 and T-272). The internal corners are slightly rounded as compared to the Munters modules whose corners look and feel sharper. As shown on the picture on Figure 3-14, the individual blades are positioned by spacers on about 16-inch enters and there are no internal partitions.

As shown on key Table 3-1, the test results for pressure loss are presented in graphical form on Figure 3-15 and the liquid carryover results are presented in tabular form on Table 3-5 and in graphical form on Figures 3-16 and 3-17.

Table 3-5 shows that for all inlet liquid loadings, there is no measurable carryover except for evaporation (Q_{EVAP}) from 600 to 800 fpm. The observation notes on droplet breakthrough indicate that from 800 to 900 fpm large droplet carryover is visible indicating breakthrough. The large droplet carryover appears to originate at the last bend corner. Above 900 fpm, the liquid carryover increases rapidly. In general, the droplets appear to be smaller for the Koch module than for the Munters modules. The Test 4 results with a fine aerosol showed only evaporation carryover with a fine mist visible at the ME outlet but no large droplets visible.

The pressure loss curves on Figure 3-15 for dry gas flow and four inlet liquid loadings are spread out significantly particularly at velocities above 800 fpm. This shows a moderate amount of sensitivity due to liquid in the mist eliminator passages.

3.6 Koch Module A-800

This is the only designation we have for this module. The geometry of this mist eliminator is specified on Figure 3-1 and a picture is shown on Figure 3-18.

The blade spacing is the same the B-800 module and the blade shape is the same but the module is about 2 1/2 inches shorter and has fewer bends.

As shown on key Table 3-1, the test results for pressure loss are presented in graphical form on Figure 3-19 and the liquid carryover results are presented in tabular form on Table 3-6 and in graphical form on Figures 3-20 and 3-21.

Table 3-5 shows that for all inlet liquid loadings, there is no measurable carryover except for evaporation (Q_{EVAP}) from 600 to 800 fpm except for Test 2 where a small carryover was measured at 800 fpm. The observation notes on droplet breakthrough indicate that small droplets are visible in this range of 600 to 800 fpm but in insufficient numbers to collect and measure. From 800 to 900 fpm large droplet carryover is visible indicating breakthrough that was similar to the other modules. The small and large droplet carryover appear to originate at the last bend corner. Above 900 fpm, the liquid carryover increases rapidly. The Test 4 results with a fine aerosol showed only evaporation carryover with a fine mist visible at the ME outlet but no large droplets visible.

The pressure loss curves on Figure 3-19 for dry gas flow and four inlet liquid loadings are grouped closely together showing a low level of pressure loss and a small amount of sensitivity due to liquid in the mist eliminator passages.

Figure 3-1 Geometry of the New Mist Eliminator Modules Tested at DynaGen for the Intermountain Generating Station, Units 1 and 2

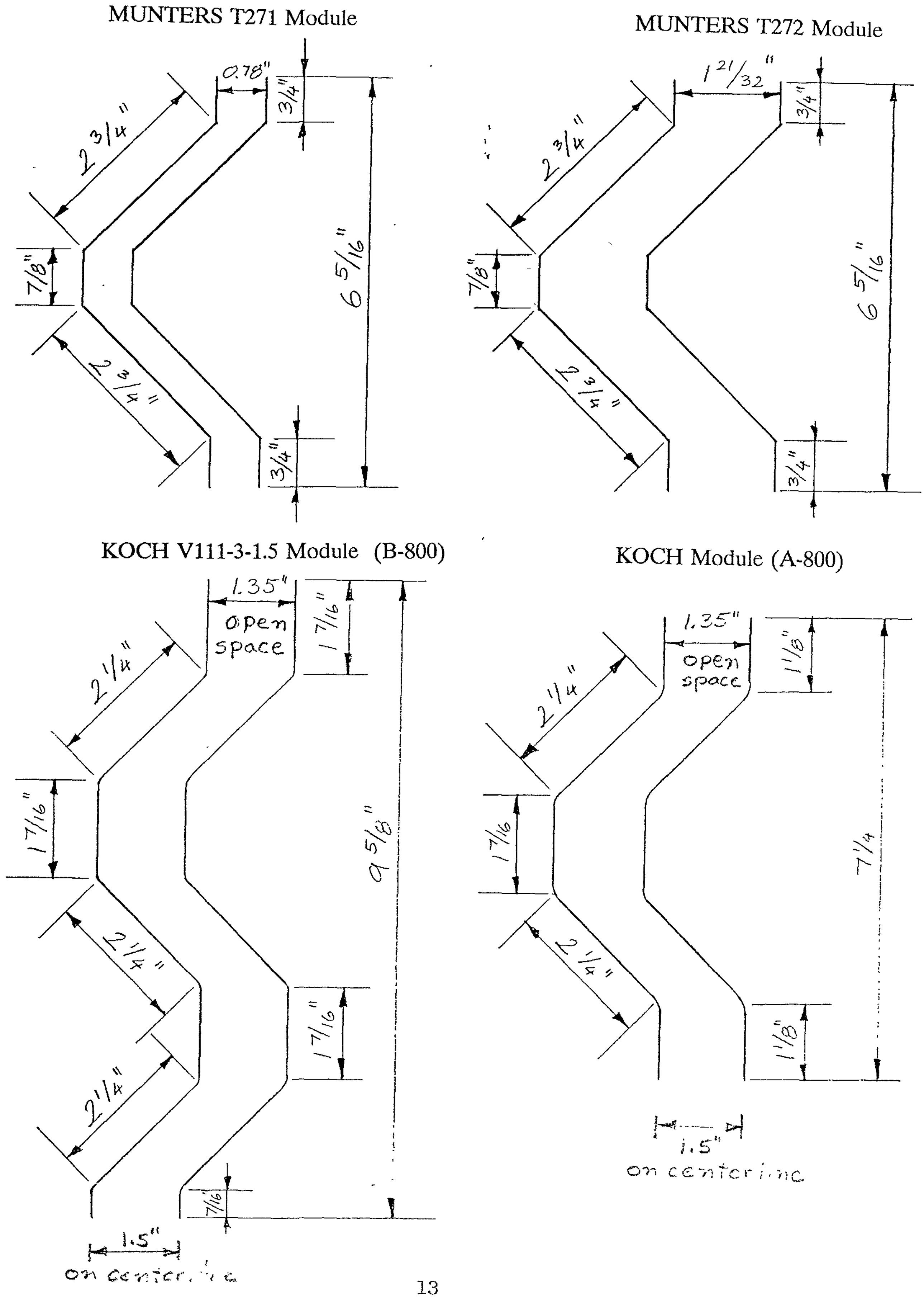

Figure 3-2 Picture of Existing Field Mist Eliminator Module

(a) Top Module Sent From Plant.
(b) Bottom Module of Same Geometry Used for Tests.

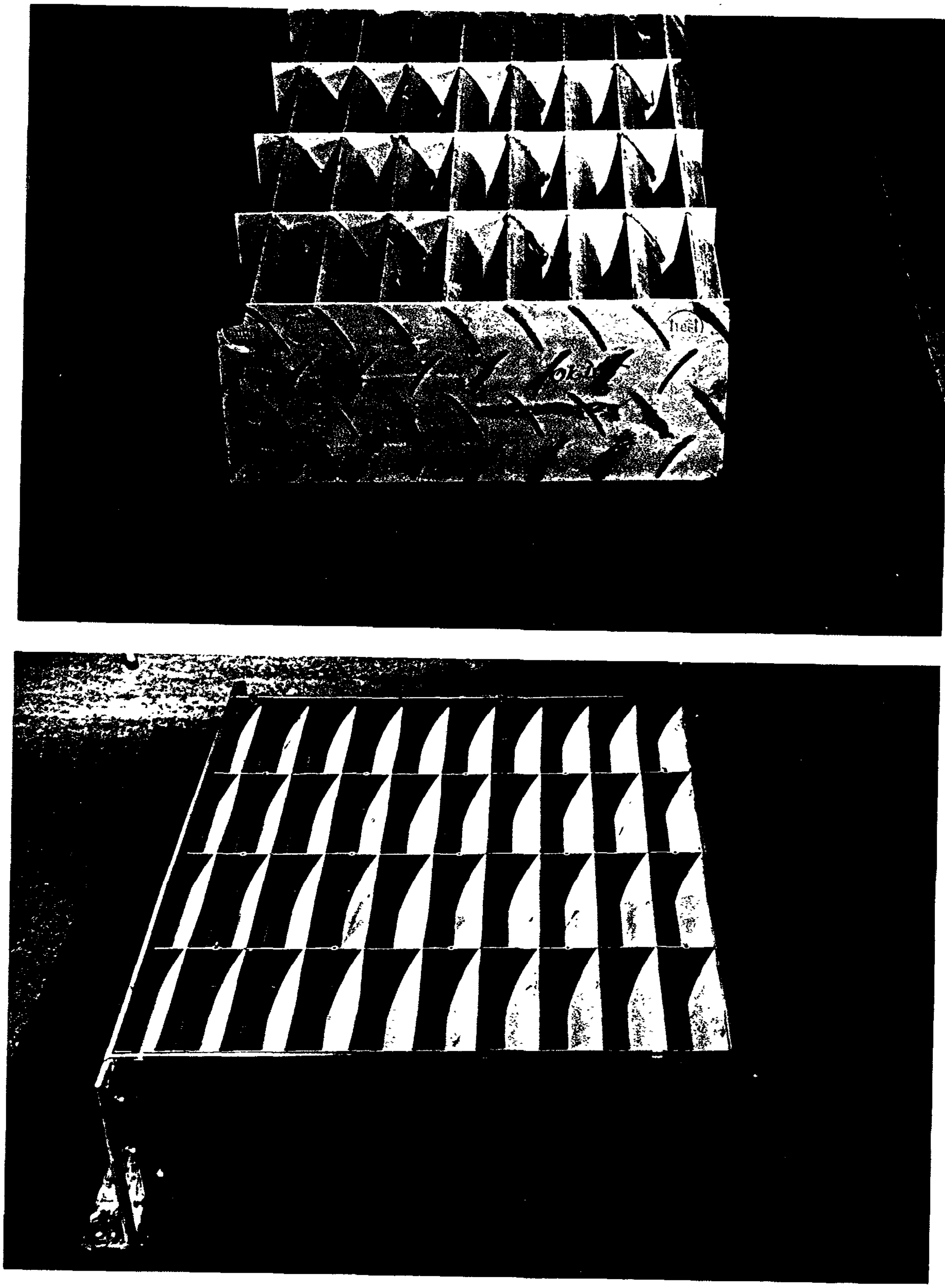

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Figure 3-3

PRESSURE LOSS FOR THE MIST ELIMINATOR MODULE
AS A FUNCTION OF GAS VELOCITY AND LIQUID LOADING

Mist Eliminator Module - FIELD MODULE - 4 PASS CHEVRON, OPEN BLADES

Notes:

(1) Test gas density is 0.076 lb/ft³ ± 2%.
(2) Pressure loss accuracy ± 0.02 inches of water.
(3) Face velocity accuracy ± 2%.

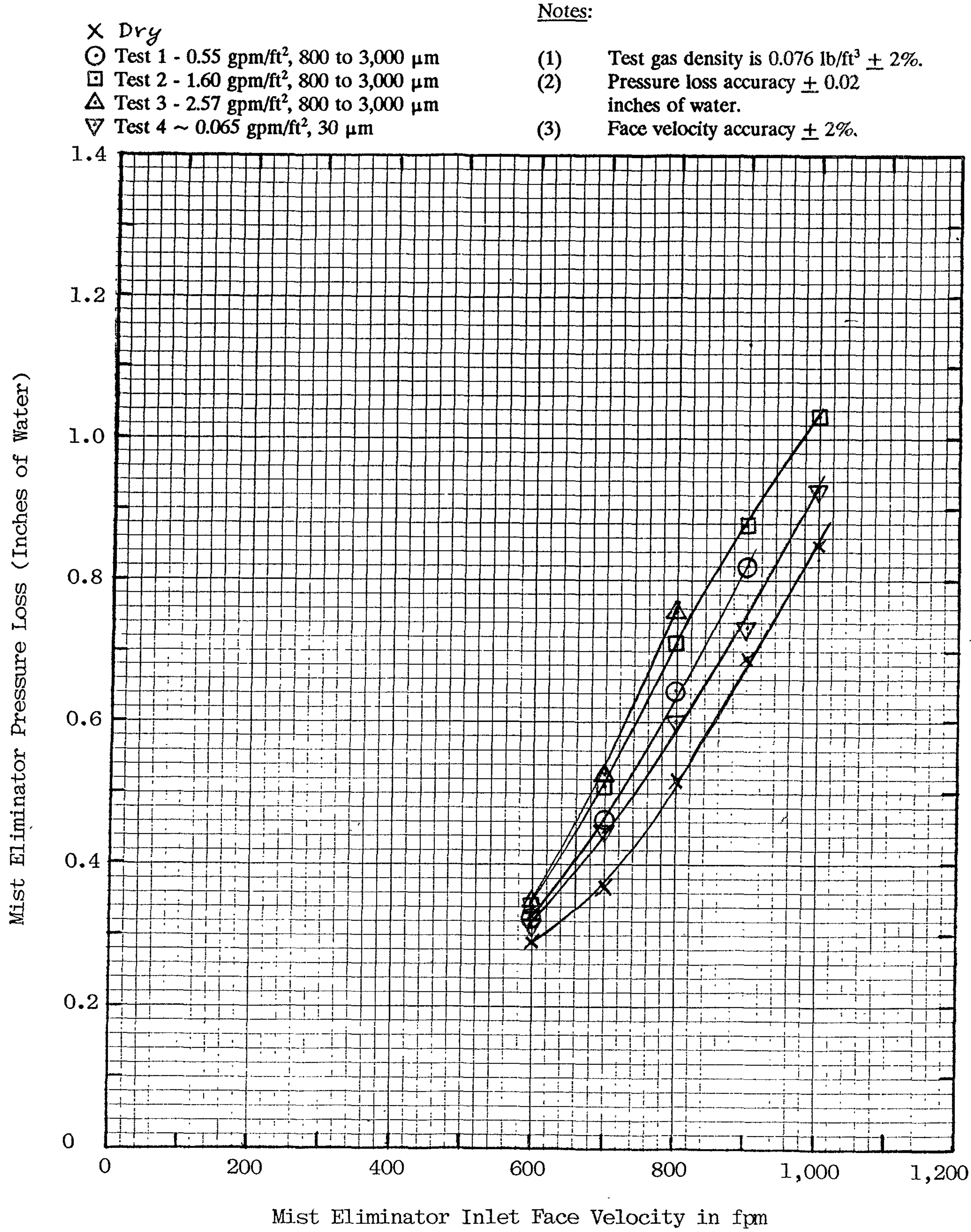

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Figure 3-4

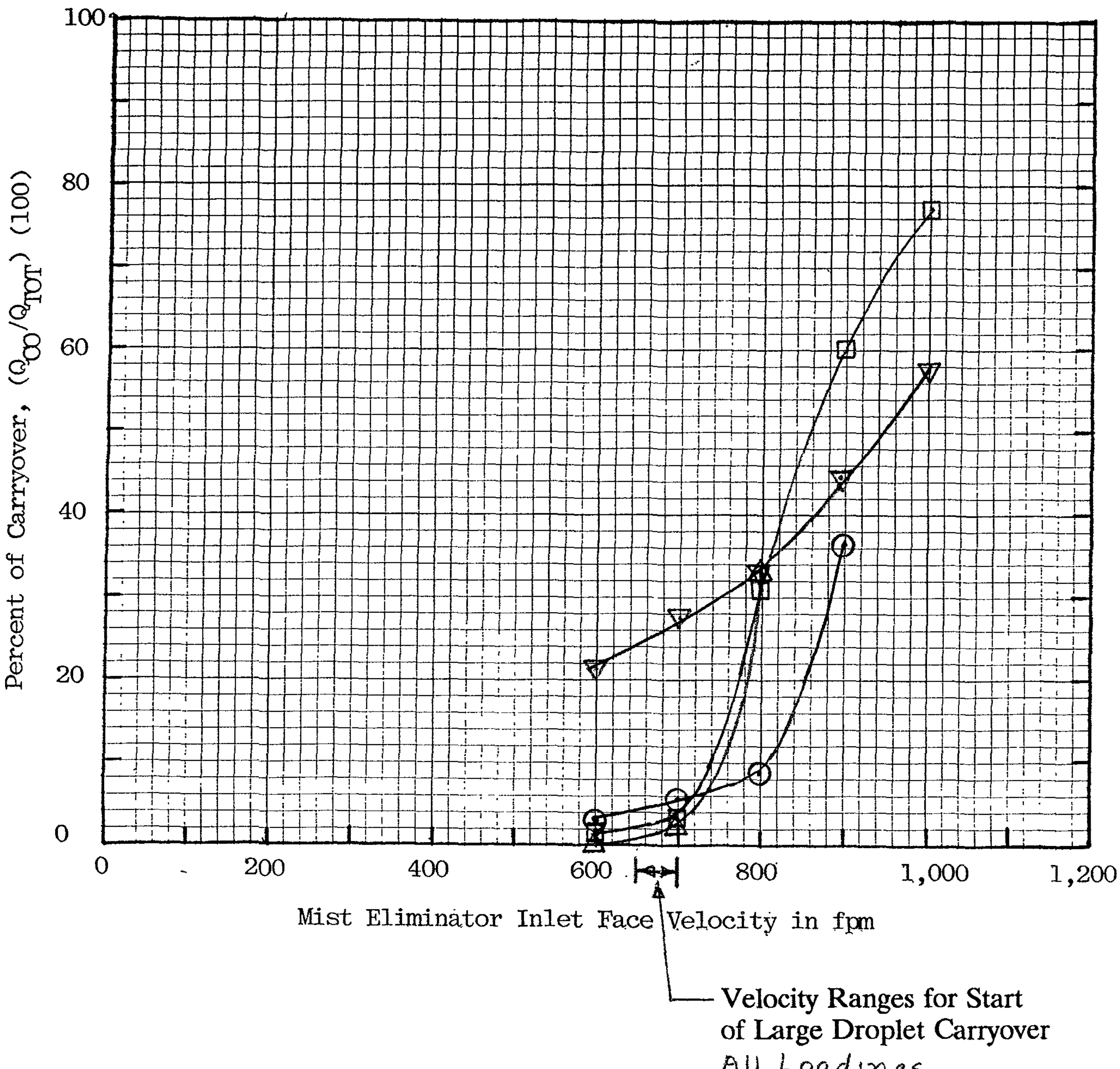
LIQUID CARRYOVER (%) FOR THE MIST ELIMINATOR MODULE
AS A FUNCTION OF GAS VELOCITY, LIQUID LOADING, AND DROPLET SIZE

Mist Eliminator Module - FIELD MODULE - 4 PASS CHEVRON; OPEN BLADES

Notes:

- ⊙ Test 1 - 0.55 gpm/ft², 800 to 3,000 μm
- ⊡ Test 2 - 1.60 gpm/ft², 800 to 3,000 μm
- △ Test 3 - 2.57 gpm/ft², 800 to 3,000 μm
- ▽ Test 4 ~ 0.065 gpm/ft², 30 μm

(1) Test gas density is 0.076 lb/ft³ ± 2%.
(2) Face velocity accuracy ± 2%.
(3) Carryover accuracy ± 3% for Tests 1, 2, 3, and ± 10% for Test 4.



IP7_039261

Figure 3-5

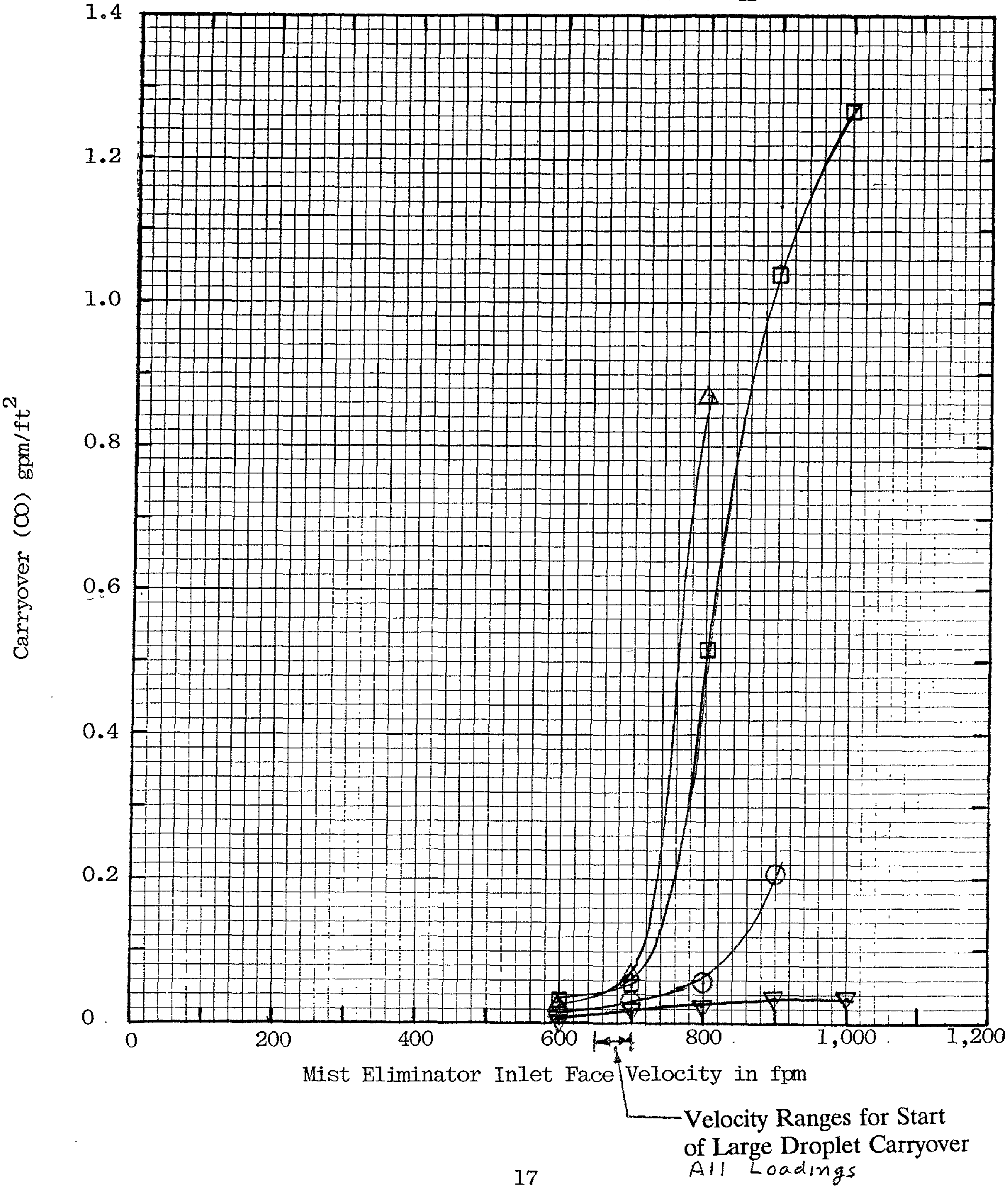
LIQUID CARRYOVER (gpm/ft²) FOR THE MIST ELIMINATOR MODULE
AS A FUNCTION OF GAS VELOCITY, LIQUID LOADING, AND DROPLET SIZE

Mist Eliminator Module - FIELD MODULE - 4 PASS CHEVRON OPEN BLADES

○ Test 1 - 0.55 gpm/ft², 800 to 3,000 μm
□ Test 2 - 1.60 gpm/ft², 800 to 3,000 μm
△ Test 3 - 2.57 gpm/ft², 800 to 3,000 μm
▽ Test 4 ~ 0.065 gpm/ft², 30 μm

Notes:

(1) Test gas density is 0.076 lb/ft³ ± 2%.
(2) Face velocity accuracy ± 2%.
(3) Carryover accuracy ± 3% for Tests 1, 2, 3, and ± 10% for Test 4.



IP7_039262

Figure 3-6 Picture of Munters T-271 Module With Geometry On Figure 3-1

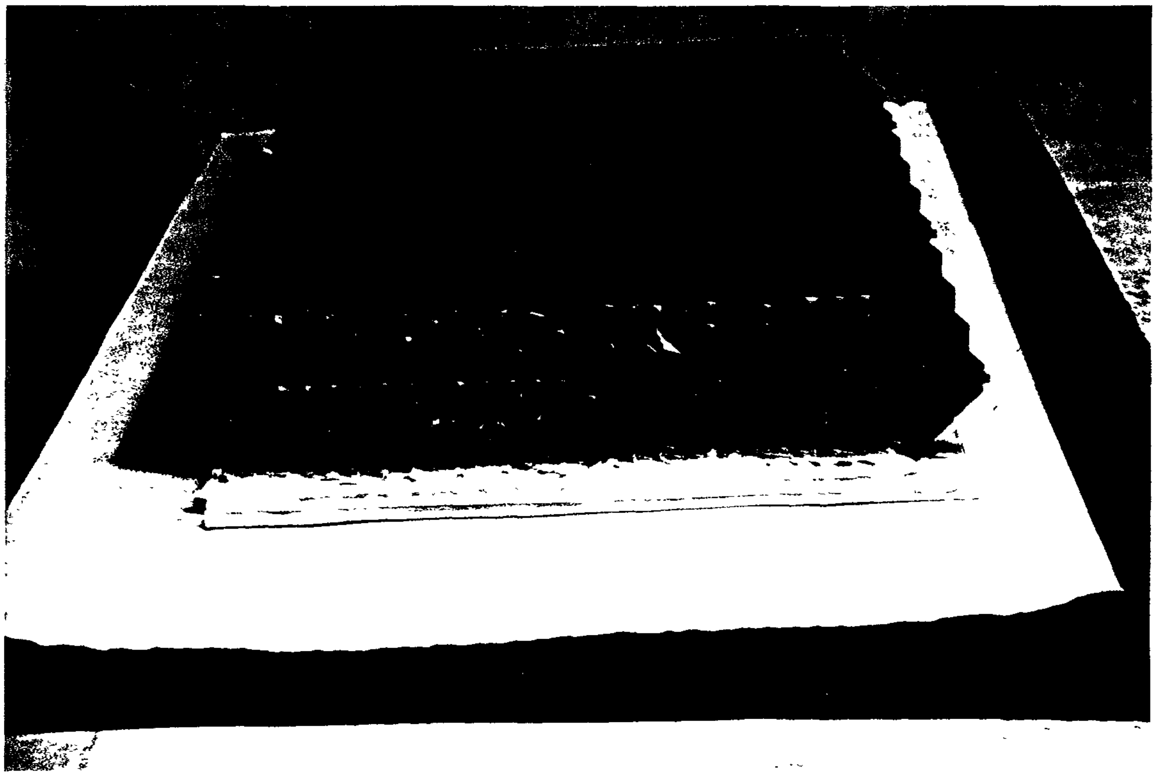


Figure 3-7

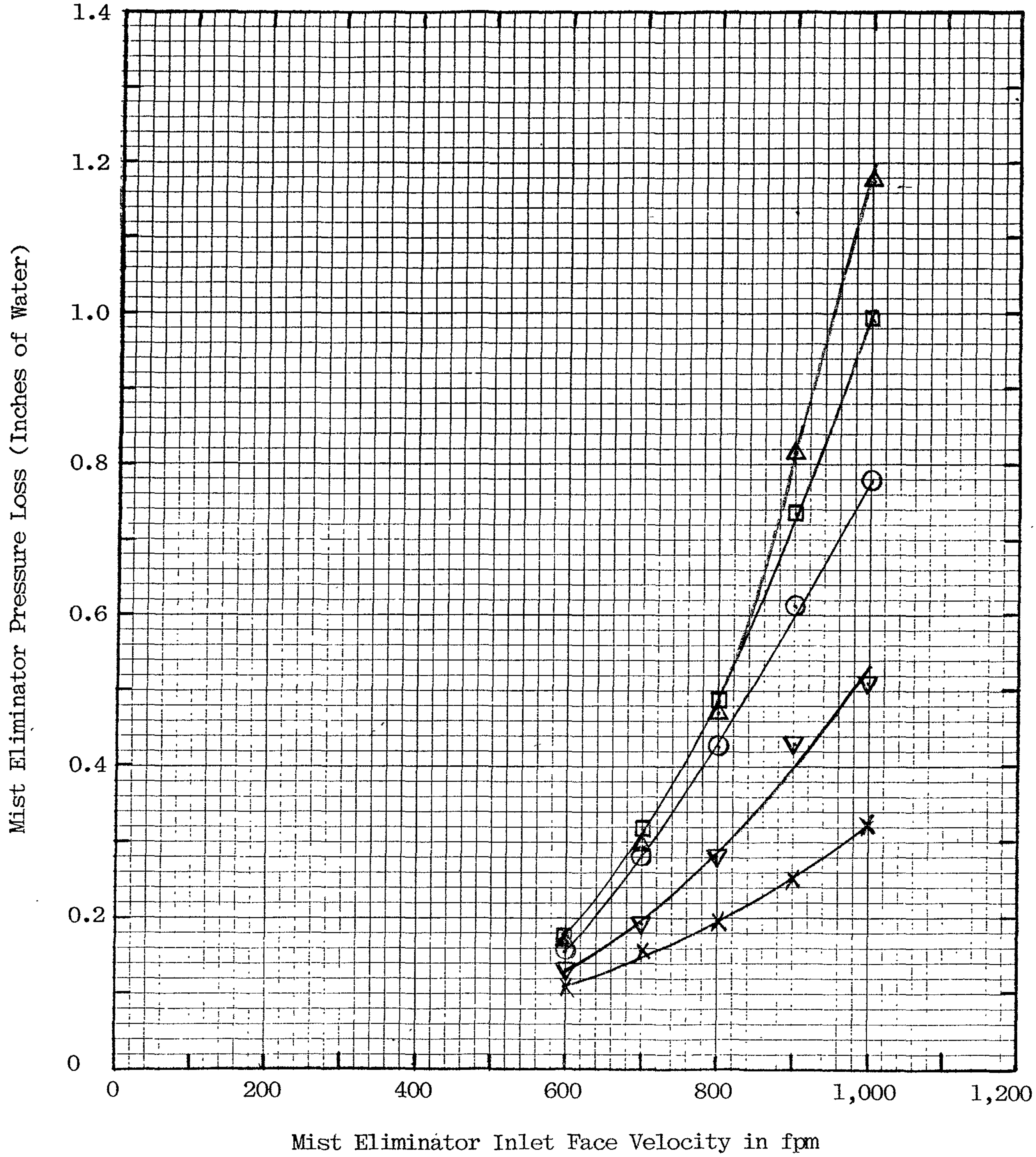
PRESSURE LOSS FOR THE MIST ELIMINATOR MODULE
AS A FUNCTION OF GAS VELOCITY AND LIQUID LOADING

Mist Eliminator Module Munters T271 Close Spaced (0.875")
0.75" Discharge Straight Piece

X Dry
⊙ Test 1 - 0.55 gpm/ft², 800 to 3,000 μm
⊡ Test 2 - 1.60 gpm/ft², 800 to 3,000 μm
△ Test 3 - 2.57 gpm/ft², 800 to 3,000 μm
▽ Test 4 ~ 0.065 gpm/ft², 30 μm

Notes:

(1) Test gas density is 0.076 lb/ft³ ± 2%.
(2) Pressure loss accuracy ± 0.02 inches of water.
(3) Face velocity accuracy ± 2%.



IP7_039264

Figure 3-8

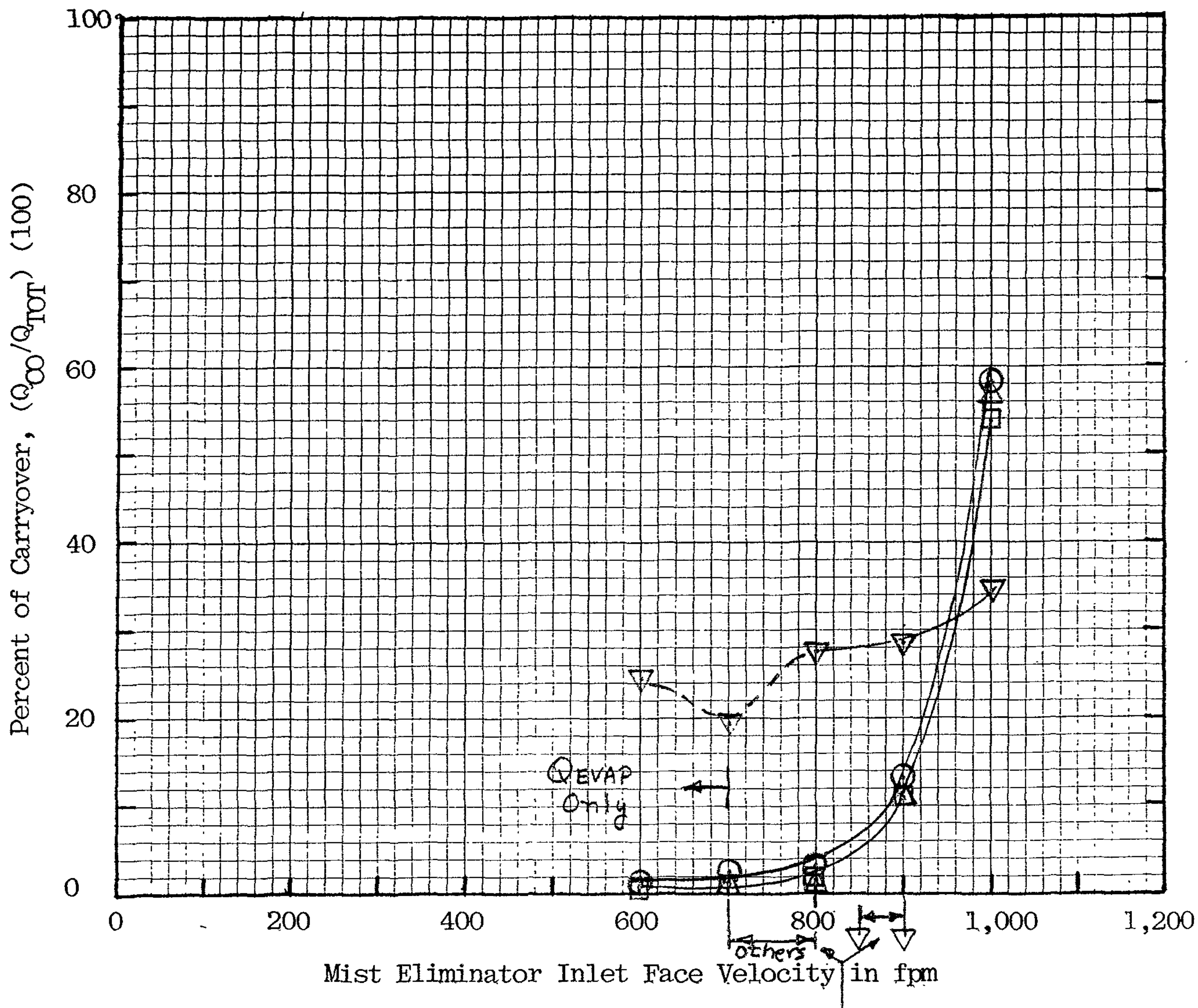
LIQUID CARRYOVER (%) FOR THE MIST ELIMINATOR MODULE
AS A FUNCTION OF GAS VELOCITY, LIQUID LOADING, AND DROPLET SIZE

Mist Eliminator Module Munters T271 Close Spaced (0.875").
0.75" Discharge Straight Piece

Test 1 - 0.55 gpm/ft², 800 to 3,000 μm
Test 2 - 1.60 gpm/ft², 800 to 3,000 μm
Test 3 - 2.57 gpm/ft², 800 to 3,000 μm
Test 4 ~ 0.065 gpm/ft², 30 μm

Notes:

(1) Test gas density is 0.076 lb/ft³ ± 2%.
(2) Face velocity accuracy ± 2%.
(3) Carryover accuracy ± 3% for Tests 1, 2, 3, and ± 10% for Test 4.



Velocity Ranges for Start of Large Droplet Carryover

IP7_039265

Figure 3-9

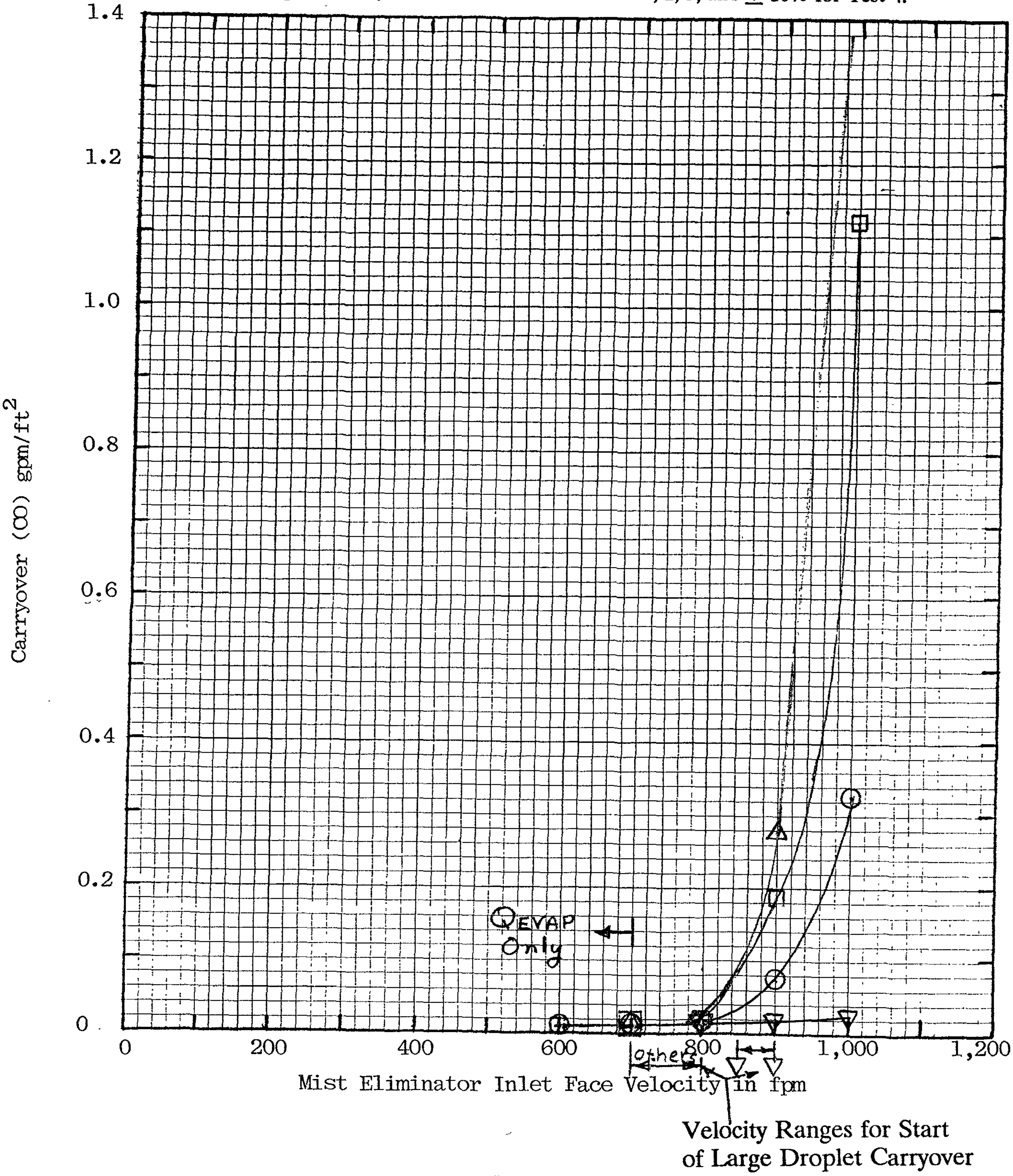
LIQUID CARRYOVER (gpm/ft²) FOR THE MIST ELIMINATOR MODULE
AS A FUNCTION OF GAS VELOCITY, LIQUID LOADING, AND DROPLET SIZE

Mist Eliminator Module Munters T271 Close Spaced (0.875") 0.75" Discharge Straight Piece

Test 1 - 0.55 gpm/ft², 800 to 3,000 μm
Test 2 - 1.60 gpm/ft², 800 to 3,000 μm
Test 3 - 2.57 gpm/ft², 800 to 3,000 μm
Test 4 ~ 0.065 gpm/ft², 30 μm

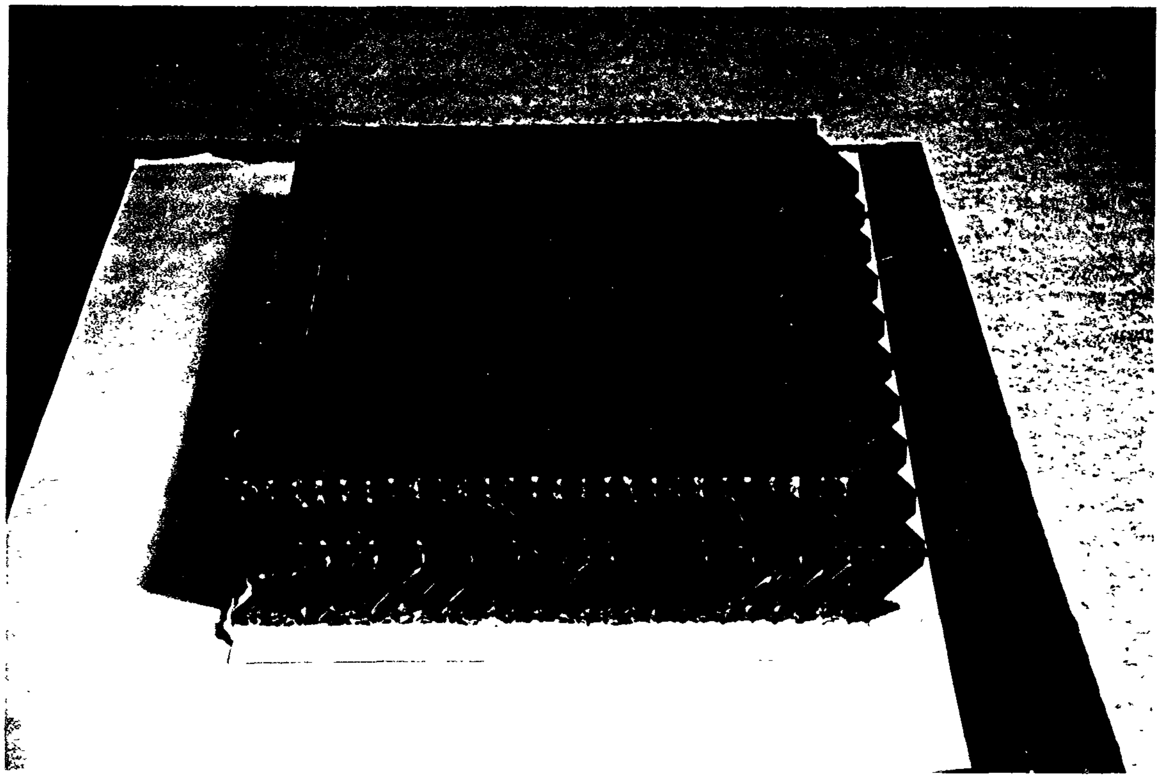
Notes:

(1) Test gas density is 0.076 lb/ft³ ± 2%.
(2) Face velocity accuracy ± 2%.
(3) Carryover accuracy ± 3% for Tests 1, 2, 3, and ± 10% for Test 4.



IP7_039266

Figure 3-10 Picture of Munters T-272 Module With Geometry On Figure 3-1



IP7_039267

Figure 3-11

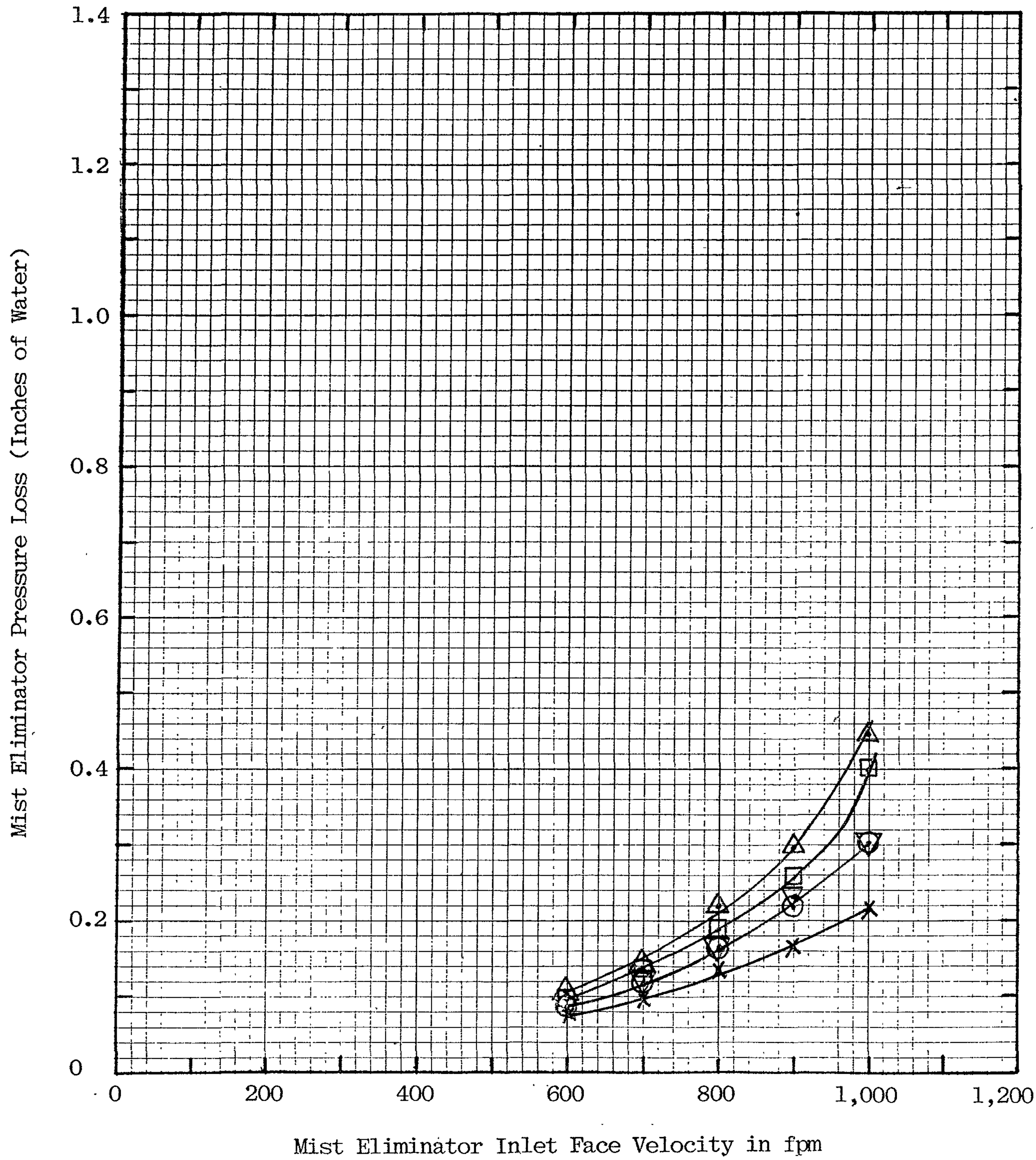
PRESSURE LOSS FOR THE MIST ELIMINATOR MODULE
AS A FUNCTION OF GAS VELOCITY AND LIQUID LOADING

Mist Eliminator Module Munters T272 - Wide Spaced (1.75")
0.75" Discharge Straight Piece

X Dry
⊙ Test 1 - 0.55 gpm/ft², 800 to 3,000 μm
⊡ Test 2 - 1.60 gpm/ft², 800 to 3,000 μm
△ Test 3 - 2.57 gpm/ft², 800 to 3,000 μm
▽ Test 4 ~ 0.065 gpm/ft², 30 μm

Notes:

(1) Test gas density is 0.076 lb/ft³ ± 2%.
(2) Pressure loss accuracy ± 0.02 inches of water.
(3) Face velocity accuracy ± 2%.



IP7_039268

Figure 3-12

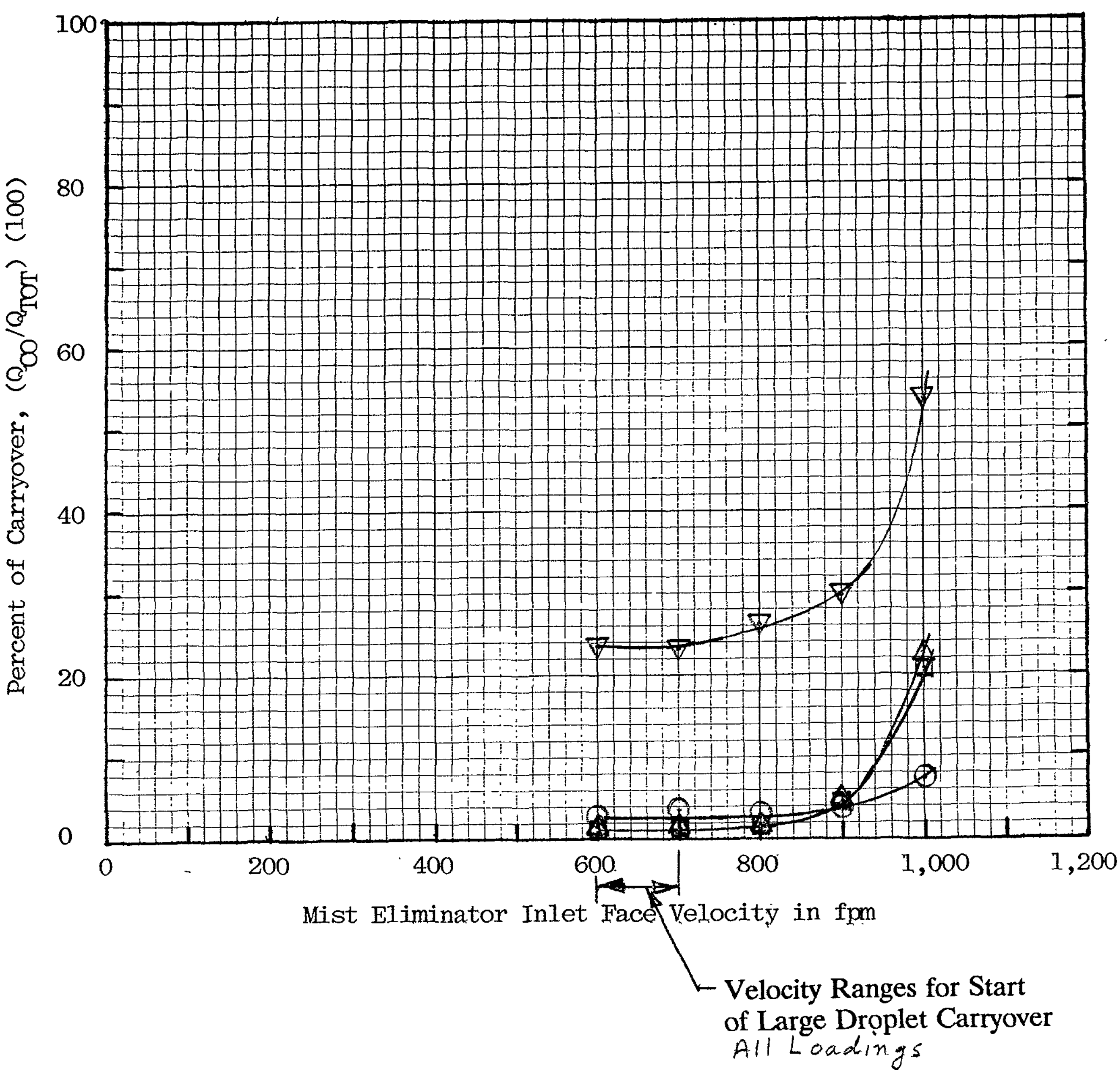
LIQUID CARRYOVER (%) FOR THE MIST ELIMINATOR MODULE
AS A FUNCTION OF GAS VELOCITY, LIQUID LOADING, AND DROPLET SIZE

Mist Eliminator Module Munters T272 Wide Spaced (1.75")
0.75" Discharge Straight Piece

- ⊙ Test 1 - 0.55 gpm/ft^2, 800 to 3,000 μm
- ⊡ Test 2 - 1.60 gpm/ft^2, 800 to 3,000 μm
- △ Test 3 - 2.57 gpm/ft^2, 800 to 3,000 μm
- ▽ Test 4 ~ 0.065 gpm/ft^2, 30 μm

Notes:

(1) Test gas density is 0.076 lb/ft^3 ± 2%.
(2) Face velocity accuracy ± 2%.
(3) Carryover accuracy ± 3% for Tests 1, 2, 3, and ± 10% for Test 4.



IP7_039269

Figure 3-13

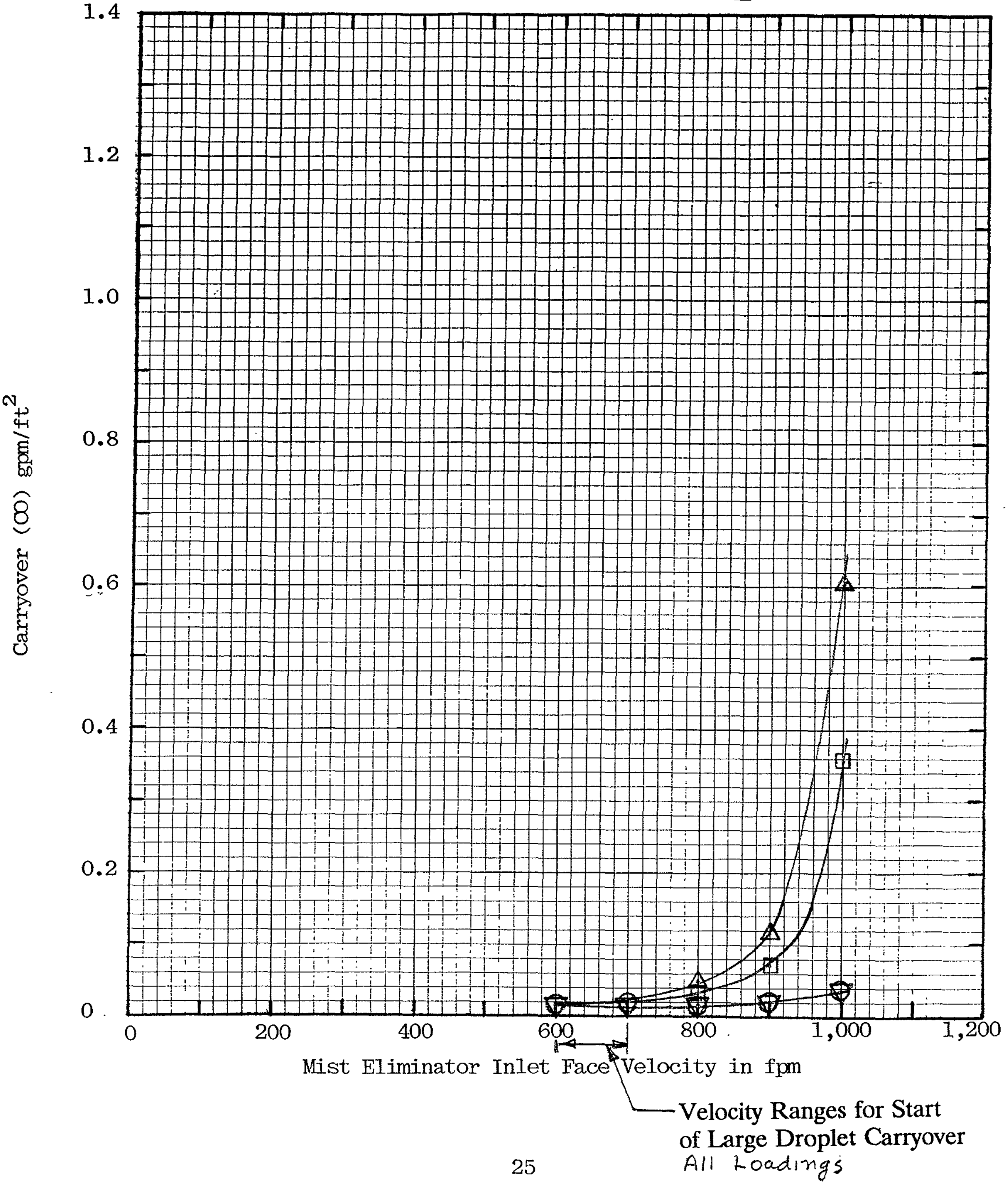
LIQUID CARRYOVER (gpm/ft²) FOR THE MIST ELIMINATOR MODULE
AS A FUNCTION OF GAS VELOCITY, LIQUID LOADING, AND DROPLET SIZE

Mist Eliminator Module Munters T272 - Wide Spaced (1.75")
0.75" Discharge Straight Piece

Notes:

- ⊙ Test 1 - 0.55 gpm/ft², 800 to 3,000 μm
- ⊡ Test 2 - 1.60 gpm/ft², 800 to 3,000 μm
- △ Test 3 - 2.57 gpm/ft², 800 to 3,000 μm
- ▽ Test 4 ~ 0.065 gpm/ft², 30 μm

(1) Test gas density is 0.076 lb/ft³ ± 2%.
(2) Face velocity accuracy ± 2%.
(3) Carryover accuracy ± 3% for Tests 1, 2, 3, and ± 10% for Test 4.



IP7_039270

Figure 3-14 Picture of Koch Module Labeled B-800 Believed to Be Model V111-3-1.5 (9 5/8" Depth) With Geometry On Figure 3-1

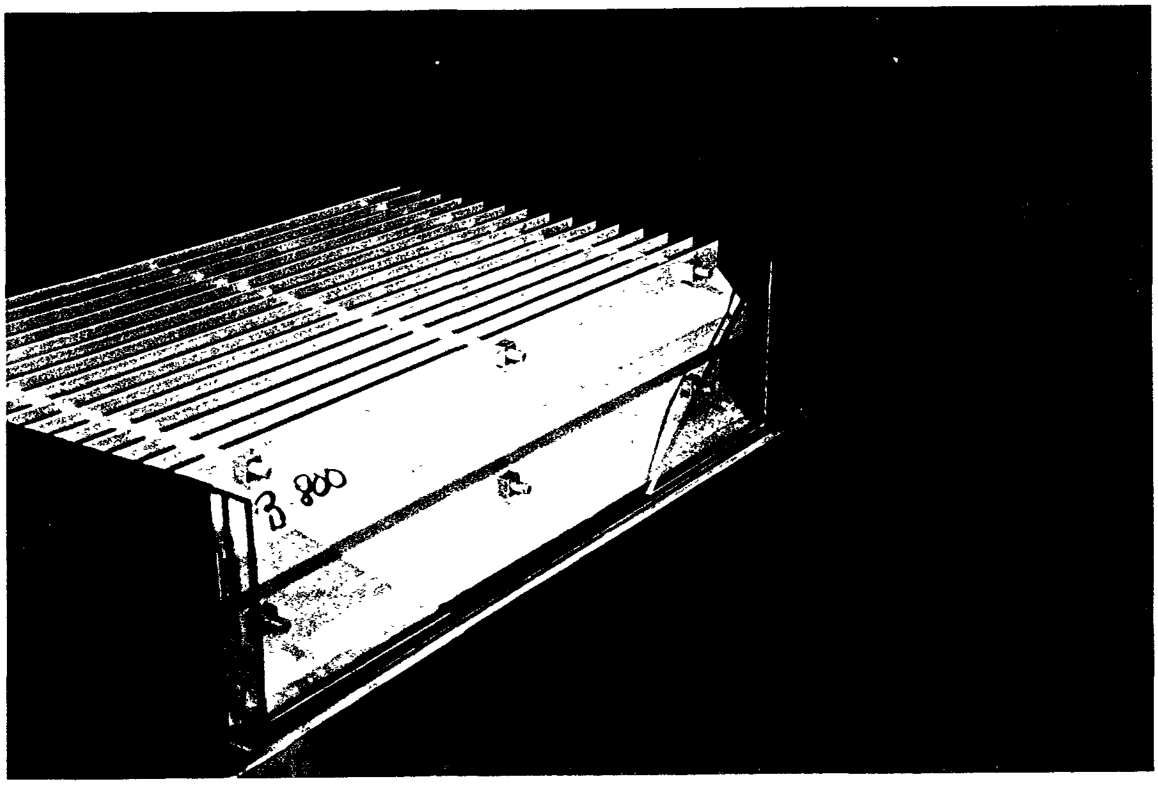


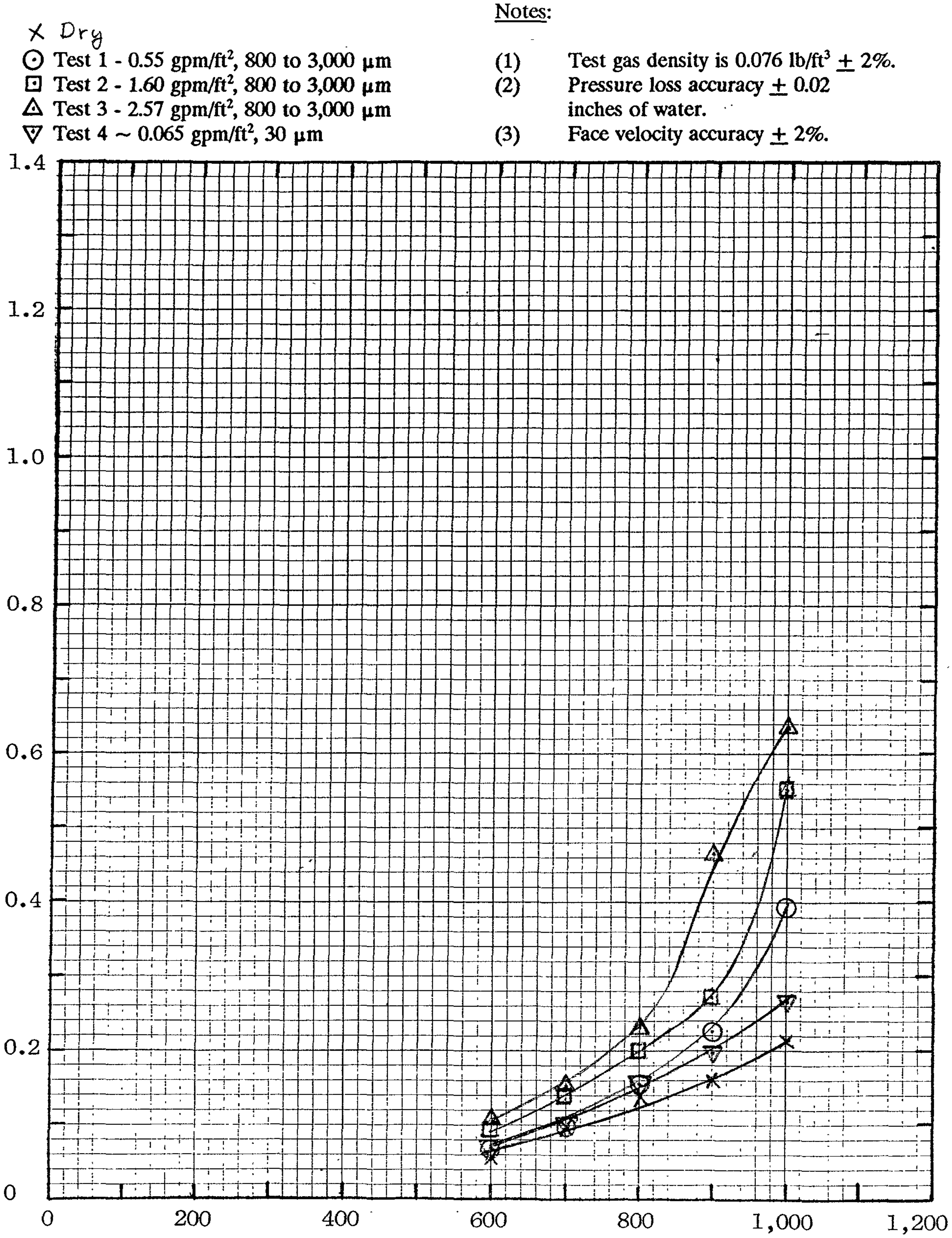
Figure 3-15

PRESSURE LOSS FOR THE MIST ELIMINATOR MODULE
AS A FUNCTION OF GAS VELOCITY AND LIQUID LOADING

Mist Eliminator Module Koch 4 Pass Module V111-3-1.5
1.5" Space B-800

Notes:

(1) Test gas density is 0.076 lb/ft³ ± 2%.
(2) Pressure loss accuracy ± 0.02 inches of water.
(3) Face velocity accuracy ± 2%.



IP7_039272

Figure 3-16

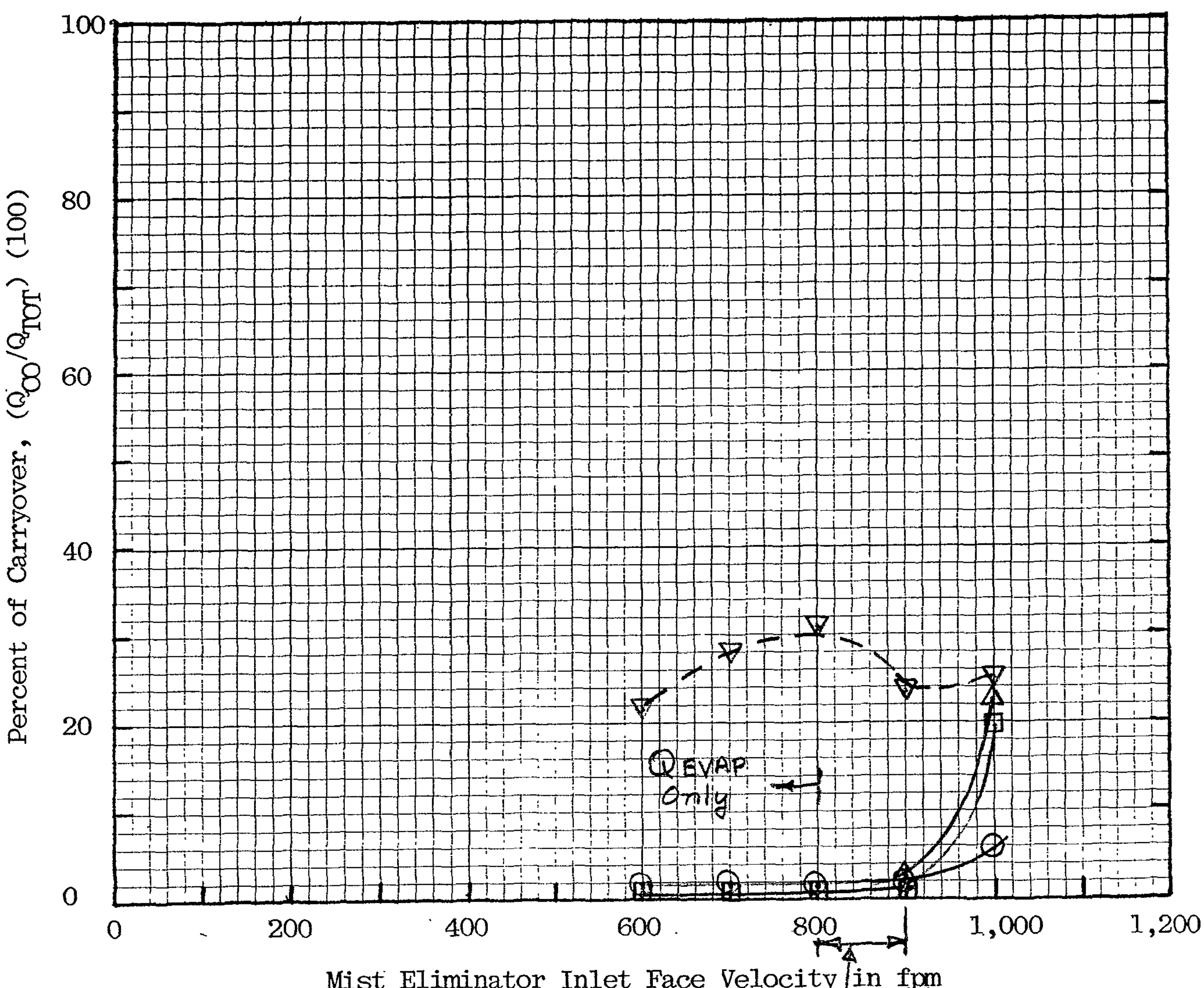
LIQUID CARRYOVER (%) FOR THE MIST ELIMINATOR MODULE
AS A FUNCTION OF GAS VELOCITY, LIQUID LOADING, AND DROPLET SIZE

Mist Eliminator Module Koch 4 Pass Module 1.5" space VIII-3-1.5 B-800

Notes:

- ⊙ Test 1 - 0.55 gpm/ft², 800 to 3,000 μm
- ⊡ Test 2 - 1.60 gpm/ft², 800 to 3,000 μm
- △ Test 3 - 2.57 gpm/ft², 800 to 3,000 μm
- ▽ Test 4 ~ 0.065 gpm/ft², 30 μm

(1) Test gas density is 0.076 lb/ft³ ± 2%.
(2) Face velocity accuracy ± 2%.
(3) Carryover accuracy ± 3% for Tests 1, 2, 3, and ± 10% for Test 4.



Velocity Ranges for Start of Large Droplet Carryover For Tests 1, 2, and 3.
No Large Droplet Carryover For Test 4 but a fine mist is visible

IP7_039273

Figure 3-17

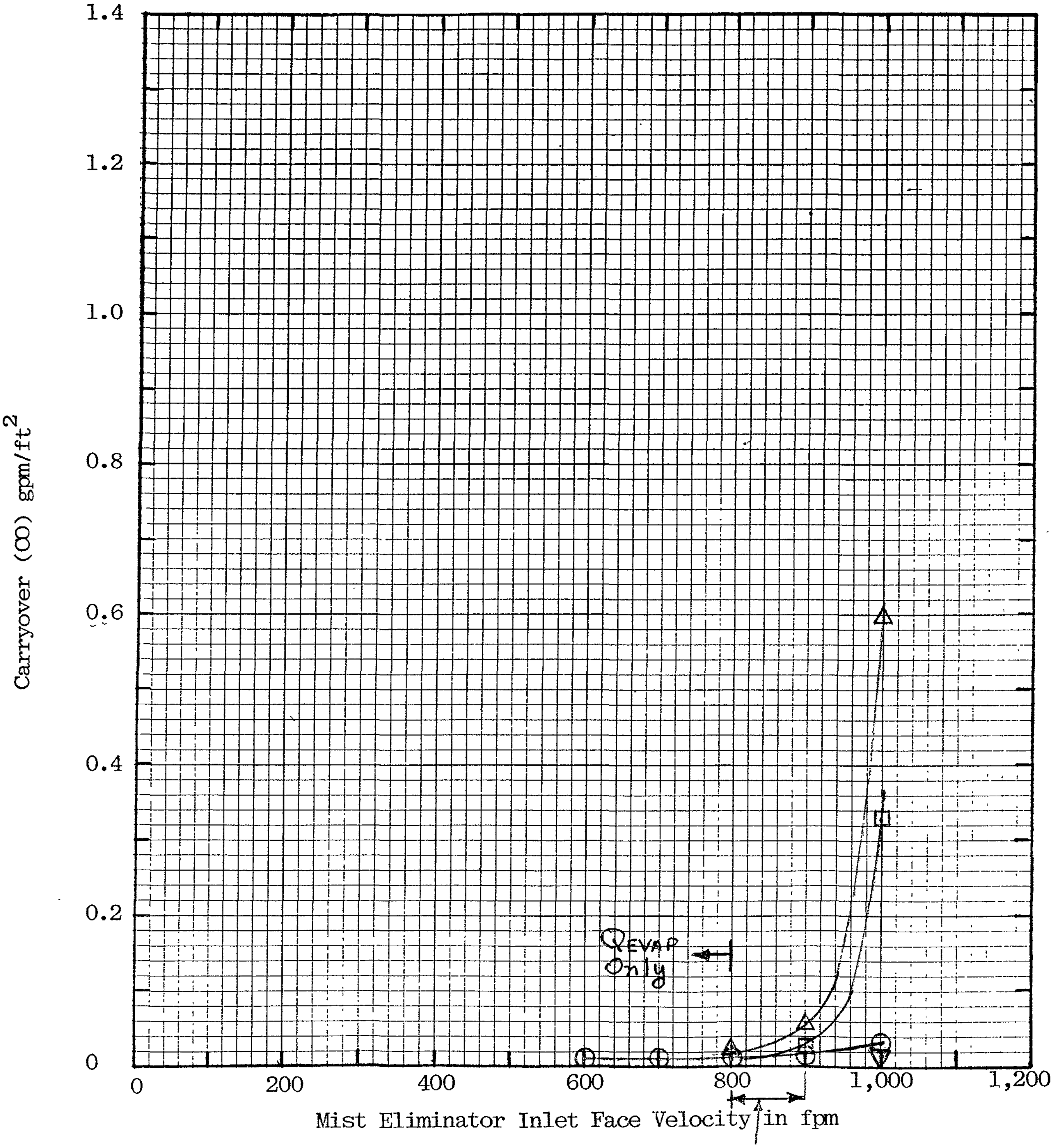
LIQUID CARRYOVER (gpm/ft^2) FOR THE MIST ELIMINATOR MODULE
AS A FUNCTION OF GAS VELOCITY, LIQUID LOADING, AND DROPLET SIZE

Mist Eliminator Module Koch 4 Pass Module V111-3-1.5
1.5" Space B-800

Notes:

- ⊙ Test 1 - 0.55 gpm/ft^2, 800 to 3,000 μm
- ⊡ Test 2 - 1.60 gpm/ft^2, 800 to 3,000 μm
- △ Test 3 - 2.57 gpm/ft^2, 800 to 3,000 μm
- ▽ Test 4 ~ 0.065 gpm/ft^2, 30 μm

(1) Test gas density is 0.076 lb/ft^3 ± 2%.
(2) Face velocity accuracy ± 2%.
(3) Carryover accuracy ± 3% for Tests 1, 2, 3, and ± 10% for Test 4.



Velocity Ranges for Start of Large Droplet Carryover For Tests 1, 2, and 3.
No Large Droplet Carryover For Test 4

IP7_039274

Figure 3-18 Picture of Koch Module Labeled A-800 (7 1/4" Depth) With Geometry On Figure 3-1

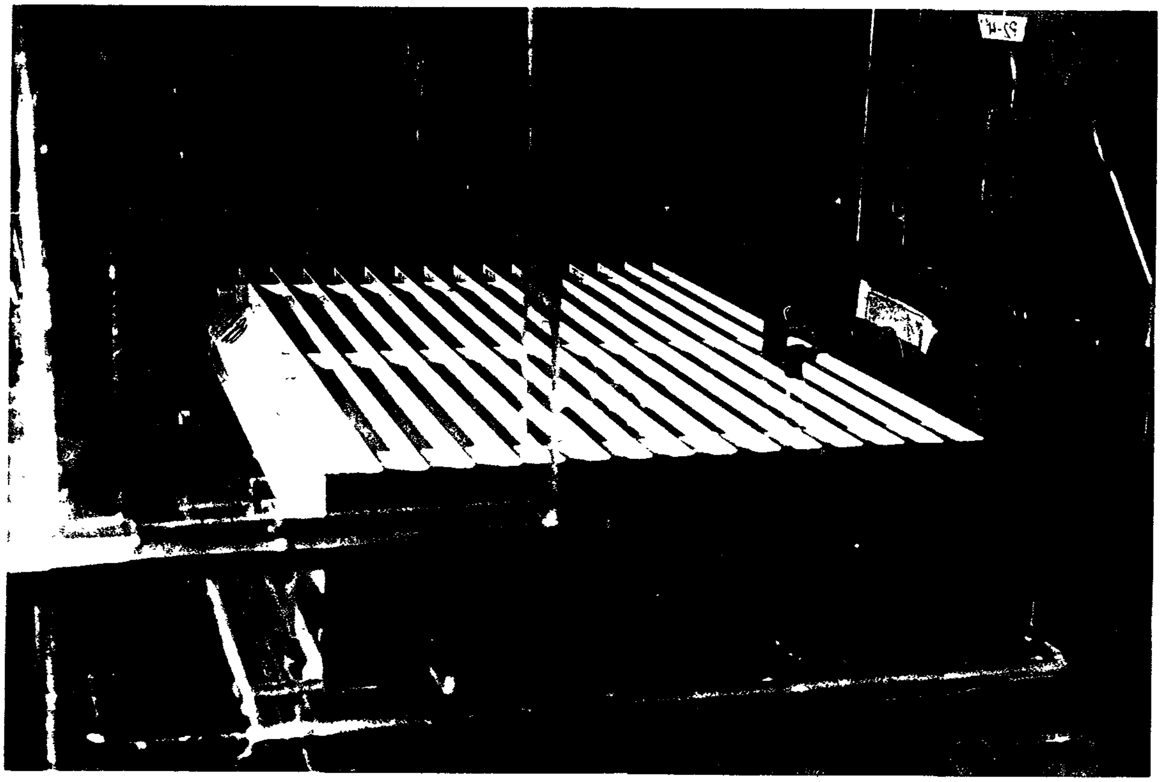


Figure 3-19

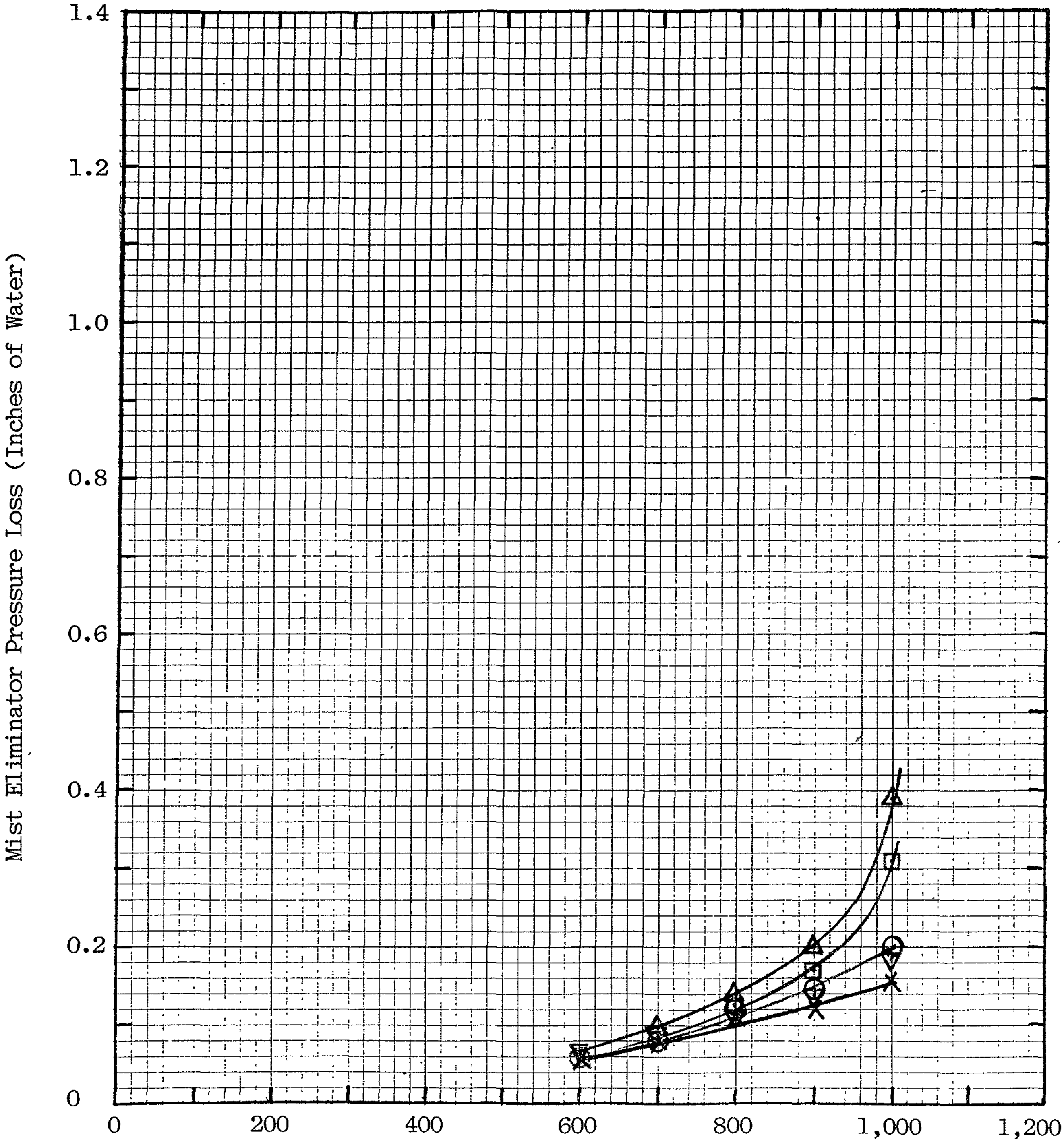
PRESSURE LOSS FOR THE MIST ELIMINATOR MODULE
AS A FUNCTION OF GAS VELOCITY AND LIQUID LOADING

Mist Eliminator Module Koch 2 Pass A-800

× Dry
⊙ Test 1 - 0.55 gpm/ft², 800 to 3,000 μm
⊡ Test 2 - 1.60 gpm/ft², 800 to 3,000 μm
△ Test 3 - 2.57 gpm/ft², 800 to 3,000 μm
▽ Test 4 ~ 0.065 gpm/ft², 30 μm

Notes:

(1) Test gas density is 0.076 lb/ft³ ± 2%.
(2) Pressure loss accuracy ± 0.02 inches of water.
(3) Face velocity accuracy ± 2%.



IP7_039276

Figure 3-20

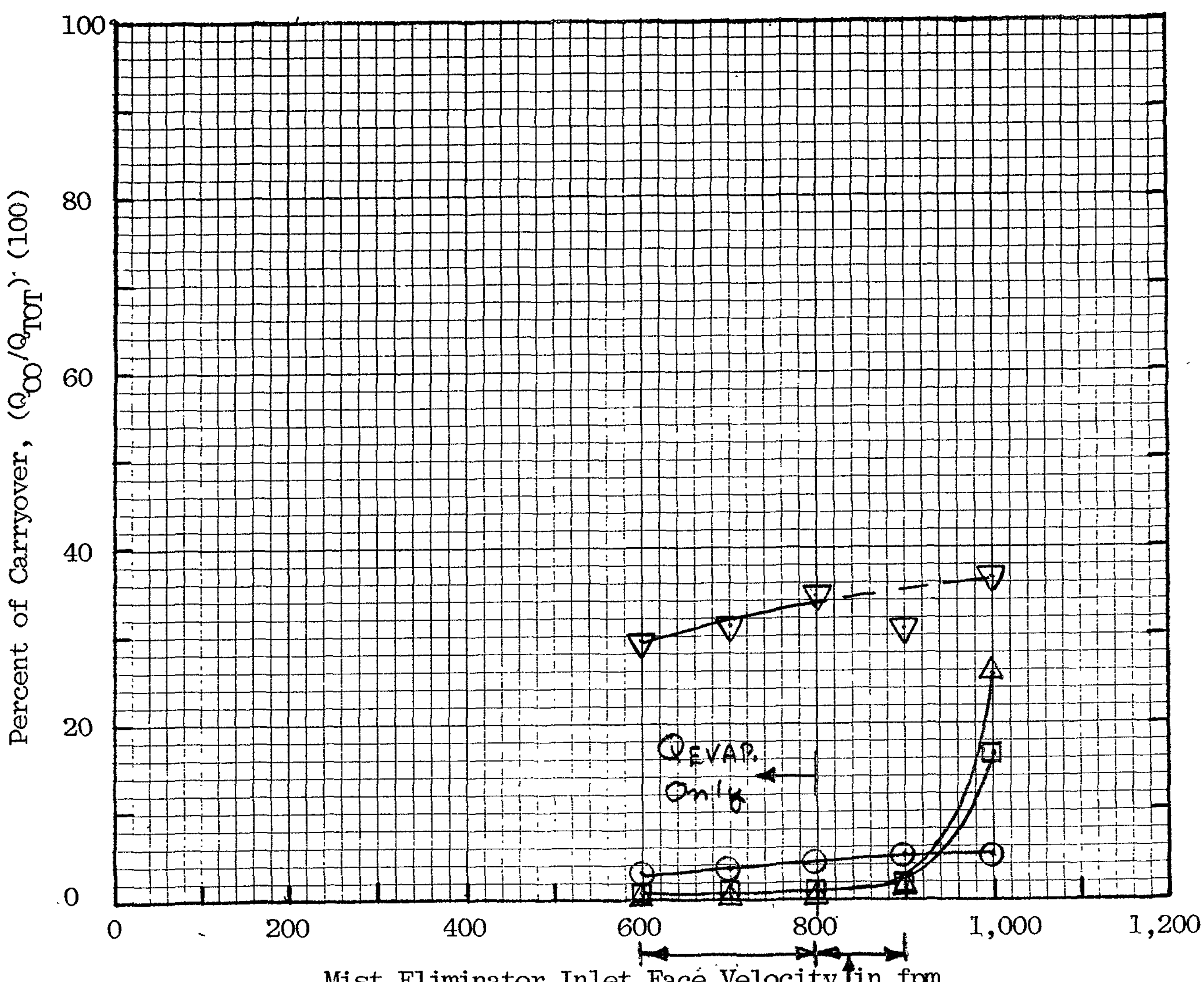
LIQUID CARRYOVER (%) FOR THE MIST ELIMINATOR MODULE
AS A FUNCTION OF GAS VELOCITY, LIQUID LOADING, AND DROPLET SIZE

Mist Eliminator Module Koch 2 Pass A-800

- ⊙ Test 1 - 0.55 gpm/ft², 800 to 3,000 μm
- ⊡ Test 2 - 1.60 gpm/ft², 800 to 3,000 μm
- △ Test 3 - 2.57 gpm/ft², 800 to 3,000 μm
- ▽ Test 4 ~ 0.065 gpm/ft², 30 μm

Notes:

(1) Test gas density is 0.076 lb/ft³ ± 2%.
(2) Face velocity accuracy ± 2%.
(3) Carryover accuracy ± 3% for Tests 1, 2, 3, and ± 10% for Test 4.



Same Droplets Seen In This Range For Tests 1, 2, and 3

Velocity Ranges for Start of Large Droplet Carryover For Tests 1, 2, and 3
No Large Droplet Carryover Test 4 But A Fine Mist Is Visible

IP7_039277

Figure 3-21

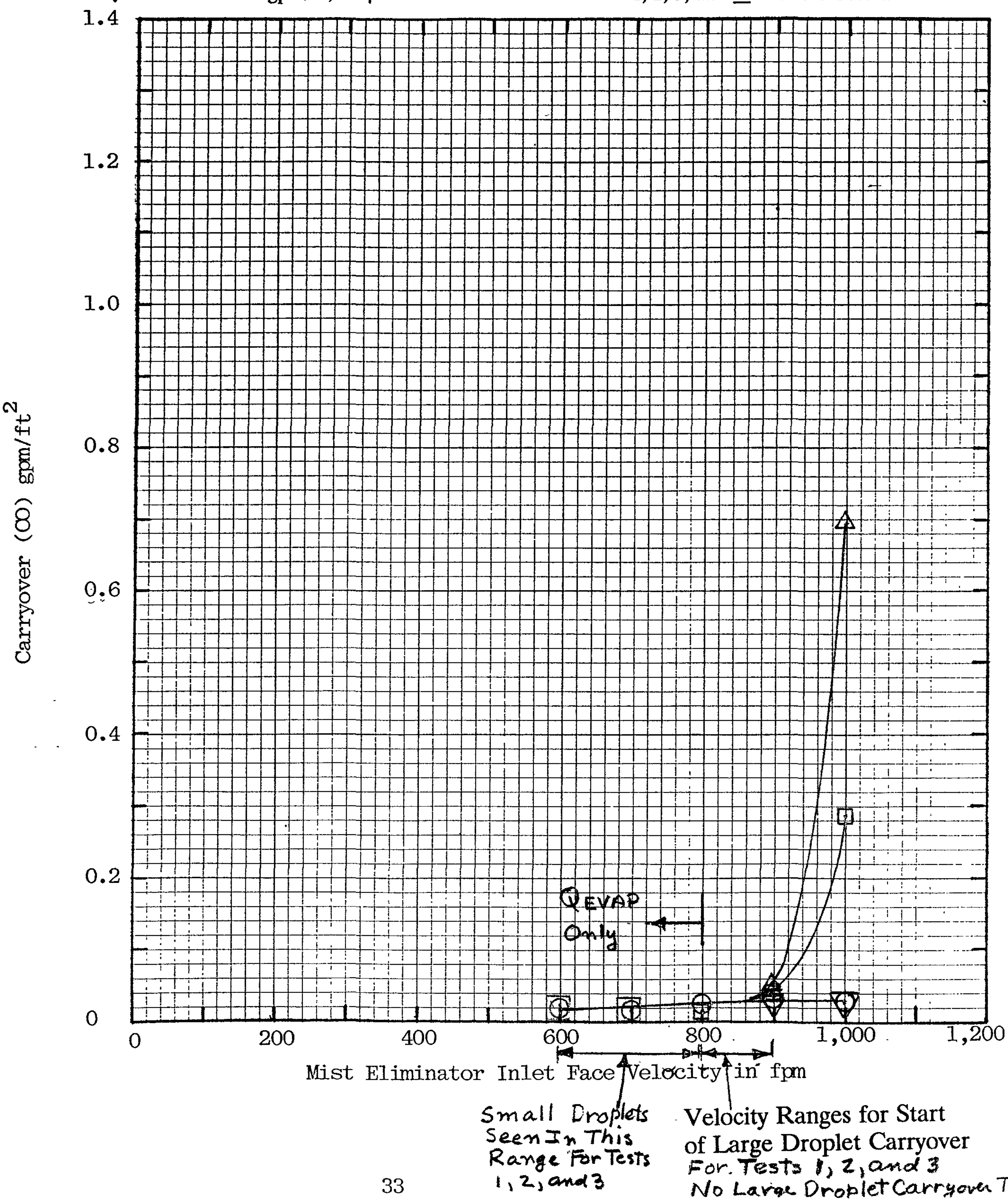
LIQUID CARRYOVER (gpm/ft²) FOR THE MIST ELIMINATOR MODULE
AS A FUNCTION OF GAS VELOCITY, LIQUID LOADING, AND DROPLET SIZE

Mist Eliminator Module Koch 2 Pass A-800

Notes:

⊙ Test 1 - 0.55 gpm/ft², 800 to 3,000 μm
⊡ Test 2 - 1.60 gpm/ft², 800 to 3,000 μm
△ Test 3 - 2.57 gpm/ft², 800 to 3,000 μm
▽ Test 4 ~ 0.065 gpm/ft², 30 μm

(1) Test gas density is 0.076 lb/ft³ ± 2%.
(2) Face velocity accuracy ± 2%.
(3) Carryover accuracy ± 3% for Tests 1, 2, 3, and ± 10% for Test 4.



IP7_039278

Table 3-1

KEY FOR LOCATION OF DATA FOR
FIVE MIST ELIMINATORS TESTED
FOR THE INTERMOUNTAIN GENERATING STATION

ME Test Module	Summary Table of Mist Eliminator Carryover Results	Picture Figure	Pressure Loss Figure	% Liquid Carryover Figure	Liquid Carryover Figure (gpm/ft^2)
Field Test Module	Table 3-2	Figure 3-2	Figure 3-3	Figure 3-4	Figure 3-5
Munters T-271 Module	Table 3-3	Figure 3-6	Figure 3-7	Figure 3-8	Figure 3-9
Munters T-272 Module	Table 3-4	Figure 3-10	Figure 3-11	Figure 3-12	Figure 3-13
Koch V111-3-1.5 Module (B-800)	Table 3-5	Figure 3-14	Figure 3-15	Figure 3-16	Figure 3-17
Koch Module (A-800)	Table 3-6	Figure 3-18	Figure 3-19	Figure 3-20	Figure 3-21

Table 3-2

SUMMARY OF MIST ELIMINATOR CARRYOVER TEST RESULTS
AS A FUNCTION OF GAS VELOCITY, LIQUID LOADING, AND DROPLET SIZE
Total Carryover = $Q_{CO} = Q_{T2} + Q_{ME} + Q_{EVAP}$
Total Liquid Load = $Q_{TOT} = Q_{T1} + Q_{CO}$

TEST MODULE IS: **Field Module - 4 Pass Chevron Open Blades**
Face Area = 5.87 ft^2

Test Number and Drop Size	Approximate Inlet Loading		Vg ME Face Velocity (fpm)	Total Liquid Load Q_{TOT} (gpm)	Q_{T1} Below ME		Q_{T2} Ledge Above ME		Q_{ME} Lab Mist Eliminator		Q_{Evap}		$\frac{Q_{CO}}{Q_{TOT}}$ x 100 %	Carryover Amount	
	$\frac{gpm}{ft^2}$	$\frac{grains}{ft^3}$			gpm	% Q_{TOT}	gpm	% Q_{TOT}	gpm	% Q_{TOT}	gpm	% Q_{TOT}		$\frac{gpm}{ft^2}$	$\frac{grains}{ft^3}$
(1) 800 to 3,000 μm	0.55	53	600	3.23	3.13	96.8	0.020	0.62	0	0	0.084	2.60	3.2	0.018	1.76
		46	700	3.15	2.97	94.3	0.102	3.2	0.002	0.06	0.076	2.4	5.7	0.031	2.59
		40	800	3.24	2.89	89.3	0.219	6.8	0.021	0.65	0.105	3.3	10.7	0.059	4.31
		36	900	3.26	2.07	63.5	0.951	29.2	0.085	2.6	0.153	4.7	36.5	0.203	13.2
		32	1000	--	--	--	--	--	--	--	--	--	--	--	--
(2) 800 to 3,000 μm	1.60	156	600	10.15	9.97	98.2	0.087	0.9	0	0	0.093	0.9	1.8	0.031	3.02
		134	700	9.63	9.34	97.0	0.26	2.7	0	0	0.033	0.3	3.0	0.050	4.18
		117	800	9.82	6.78	69.0	2.79	28.4	0.16	1.6	0.093	1.0	31.0	0.518	3.79
		104	900	10.19	4.08	40.0	5.41	53.1	0.51	5.0	0.191	1.9	60.0	1.04	67.6
		94	1000	9.68	2.23	23.0	6.70	69.2	0.60	6.2	0.150	1.6	77.0	1.27	74.3
(3) 800 to 3,000 μm	2.57	250	600	15.59	15.43	99.0	0.124	0.8	0	0	0.036	0.2	1.0	0.027	2.63
		215	700	15.96	15.60	97.7	0.320	2.0	0.002	0	0.042	0.3	2.3	0.062	5.18
		188	800	15.57	10.46	67.2	4.49	28.8	0.47	3.0	0.148	1.0	32.8	0.870	63.6
		167	900	--	--	--	--	--	--	--	--	--	--	--	--
		150	1000	--	--	--	--	--	--	--	--	--	--	--	--
(4) 30 μm	0.071	6.9	600	0.424	0.331	78.1			0	0	0.093	21.9	21.9	0.016	1.56
		5.9	700	0.435	0.314	72.2			0	0	0.121	27.8	27.8	0.021	1.76
		5.2	800	0.428	0.286	66.8			0.011	2.6	0.131	30.6	33.2	0.024	1.76
		4.6	900	0.473	0.263	55.6			0.037	7.8	0.173	36.6	44.4	0.036	2.34
		4.2	1000	0.366	0.155	42.3			0.091	24.9	0.120	32.8	57.7	0.036	2.11

Table 3-3

SUMMARY OF MIST ELIMINATOR CARRYOVER TEST RESULTS
AS A FUNCTION OF GAS VELOCITY, LIQUID LOADING, AND DROPLET SIZE

Total Carryover = $Q_{CO} = Q_{T2} + Q_{ME} + Q_{EVAP}$

Total Liquid Load = $Q_{TOT} = Q_{T1} + Q_{CO}$

TEST MODULE IS: **Munters T271 Close Space (0.875")**
0.75" Discharge Straight Piece
$A_{face} = 5.64\ ft^2$

Test Number and Drop Size	Approximate Inlet Loading		Vg ME Face Velocity (fpm)	Q_{TOT} Total Liquid Load (gpm)	Q_{T1} Below ME		Q_{T2} Ledge Above ME		Q_{ME} Lab Mist Eliminator		Q_{Evap}		$\frac{Q_{CO}}{Q_{TOT}}$ x 100 %	Carryover Amount	
	$\frac{gpm}{ft^2}$	$\frac{grains}{ft^3}$			gpm	% Q_{TOT}	gpm	% Q_{TOT}	gpm	% Q_{TOT}	gpm	% Q_{TOT}		$\frac{gpm}{ft^2}$	$\frac{grains}{ft^3}$
(1) 800 to 3,000 μm	0.55	53	600	3.120	3.069	98.37	0	0	0	0	0.051	1.63	1.63	0.009	0.88
		46	700	3.094	3.019	97.58	0	0	0	0	0.075	2.42	2.42	0.013	1.11
		40	800	3.098	3.003	96.93	0	0	0	0	0.095	3.07	3.07	0.017	1.23
		36	900	3.117	2.711	86.98	0.298	9.56	0	0	0.108	3.465	13.02	0.072	4.68
		32	1000	3.145	1.320	41.97	1.458	46.36	0.238	7.57	0.129	4.10	58.03	0.324	18.93
(2) 800 to 3,000 μm	1.60	156	600	9.641	9.58	99.37	0	0	0	0	0.061	0.63	0.63	0.011	1.05
		134	700	9.701	9.629	99.26	0	0	0	0	0.072	0.74	0.74	0.013	1.07
		117	800	9.559	9.434	98.69	0.04	0.41	0	0	0.085	0.889	1.30	0.022	1.62
		104	900	9.740	8.699	89.31	0.811	8.33	0.114	1.17	0.116	1.19	10.69	0.185	12.0
		94	1000	9.619	4.429	46.04	4.445	46.21	0.631	6.56	0.114	1.19	53.96	0.920	53.8
(3) 800 to 3,000 μm	2.57	250	600	14.78	14.70	99.45	0	0	0	0	0.081	0.55	0.55	0.014	1.40
		215	700	14.91	14.81	99.33	0	0	0	0	0.100	0.67	0.67	0.018	1.48
		188	800	14.45	14.35	99.28	0	0	0	0	0.104	0.72	0.72	0.018	1.34
		167	900	15.34	13.76	89.72	1.30	8.48	0.198	1.29	0.078	0.51	10.28	0.279	18.1
		150	1000	15.19	6.55	43.12	8.075	53.16	0.412	2.71	0.153	1.01	56.88	1.53	89.6
(4) 30 μm	0.071*	* 6.9	600	0.382	0.289	75.65	0	0	0	0	0.093	24.35	24.35	0.016	1.61
		5.9	700	0.357	0.288	80.67	0	0	0	0	0.069	19.33	19.33	0.012	1.02
		5.1	800	0.398	0.288	72.36	0	0	0	0	0.110	27.64	27.64	0.020	1.43
		4.6	900	0.386	0.276	71.50	0	0	0	0	0.110	28.50	28.50	0.020	1.27
		4.2	1000	0.359	0.236	65.74	0	0	0	0	0.123	34.26	34.26	0.022	1.28

*Revised 1/4/94.

IP7_039281

Table 3-4

SUMMARY OF MIST ELIMINATOR CARRYOVER TEST RESULTS
AS A FUNCTION OF GAS VELOCITY, LIQUID LOADING, AND DROPLET SIZE

Total Carryover = $Q_{CO} = Q_{T2} + Q_{ME} + Q_{EVAP}$

Total Liquid Load = $Q_{TOT} = Q_{T1} + Q_{CO}$

TEST MODULE IS: **Munters T272 - Wide Spaced (1.75")**
0.75" Discharge Straight Piece
$A_{face} = 5.47\ ft^2$

Test Number and Drop Size	Approximate Inlet Loading		Vg ME Face Velocity (fpm)	Q_{TOT} Total Liquid Load (gpm)	Q_{T1} Below ME		Q_{T2} Ledge Above ME		Q_{ME} Lab Mist Eliminator		Q_{Evap}		$\frac{Q_{CO}}{Q_{TOT}}$ x 100 %	Carryover Amount	
	$\frac{gpm}{ft^2}$	$\frac{grains}{ft^3}$			gpm	% Q_{TOT}	gpm	% Q_{TOT}	gpm	% Q_{TOT}	gpm	% Q_{TOT}		$\frac{gpm}{ft^2}$	$\frac{grains}{ft^3}$
(1)	0.55	53	600	3.067	2.985	97.33	0	0	0	0	0.082	2.67	2.67	0.015	1.46
800 to		46	700	3.067	2.977	96.78	0	0	0	0	0.099	3.22	3.22	0.018	1.51
3,000 µm		40	800	3.063	2.982	97.36	0	0	0	0	0.081	2.64	2.64	0.015	1.08
		36	900	3.078	2.969	96.46	0.025	0.81	0.002	0.065	0.082	2.66	3.54	0.020	1.30
		32	1000	3.991	2.777	92.85	0.099	3.31	0.018	0.60	0.097	3.24	7.15	0.039	2.29
(2)	1.60	156	600	9.309	9.22	99.04	0.028	0.30	0	0	0.061	0.655	0.955	0.016	1.59
800 to		134	700	9.322	9.22	98.91	0.041	0.44	0	0	0.061	0.654	1.094	0.019	1.56
3,000 µm		117	800	9.333	9.17	98.25	0.084	0.90	0.002	0.021	0.077	0.825	1.746	0.030	2.18
		104	900	9.501	9.11	95.89	0.259	2.73	0.009	0.095	0.123	1.295	4.129	0.071	4.65
		94	1000	9.565	7.61	79.56	1.734	18.13	0.116	1.213	0.105	1.10	20.44	0.357	20.9
(3)	2.57	250	600	14.944	14.89	99.64	0.023	0.154	-	-	0.031	0.207	0.36	0.010	0.96
800 to		215	700	14.775	14.70	99.49	0.055	0.372	-	-	0.020	0.135	0.508	0.014	1.15
3,000 µm		188	800	14.732	14.47	97.94	0.141	0.954	-	-	0.121	0.819	1.77	0.048	3.50
		167	900	14.734	14.10	95.70	0.554	3.760	-	-	0.080	0.543	4.303	0.116	7.53
		150	1000	14.782	11.49	77.73	3.192	21.61	-	-	0.100	0.676	22.29	0.602	35.20
(4)	0.073*	* 7.1	600	0.394	0.302	76.65	-	-	0	0	0.092	23.35	23.35	0.017	1.64
30 µm		6.1	700	0.372	0.286	76.88	-	-	0.003	0.806	0.083	22.31	23.12	0.016	1.31
		5.3	800	0.388	0.287	73.97	-	-	0.003	0.773	0.098	25.26	26.03	0.018	1.35
		4.7	900	0.364	0.256	70.33	-	-	0.016	4.396	0.092	25.28	29.67	0.020	1.28
		4.3	1000	0.387	0.179	46.25	-	-	0.106	27.39	0.102	26.357	53.747	0.038	2.22

*Revised 1/4/94.

SUMMARY OF MIST ELIMINATOR CARRYOVER TEST RESULTS
AS A FUNCTION OF GAS VELOCITY, LIQUID LOADING, AND DROPLET SIZE

Total Carryover = $Q_{CO} = Q_{T2} + Q_{ME} + Q_{EVAP}$
Total Liquid Load = $Q_{TOT} = Q_{T1} + Q_{CO}$

TEST MODULE IS: **Koch Module, 4 Pass Deep** VIII-3-1.5 (B-800)
1.5" Space
A_{face} = 5.21 ft²

Test Number and Drop Size	Approximate Inlet Loading: gpm/ft²	Approximate Inlet Loading: grains/ft³	Vg ME Face Velocity (fpm)	Q_{TOT} Total Liquid Load (gpm)	Q_{T1} Below ME: gpm	Q_{T1} Below ME: % Q_{TOT}	Q_{T2} Ledge Above ME: gpm	Q_{T2} Ledge Above ME: % Q_{TOT}	Q_{ME} Lab Mist Eliminator: gpm	Q_{ME} Lab Mist Eliminator: % Q_{TOT}	Q_{Evap}: gpm	Q_{Evap}: % Q_{TOT}	$\frac{Q_{CO}}{Q_{TOT}}$ x 100 %	Carryover Amount: gpm/ft²	Carryover Amount: grains/ft³
(1) 800 to 3,000 μm	0.55	53	600	2.896	2.847	98.31	0	0	0	0	0.049	1.69	1.69	0.009	0.92
		46	700	2.893	2.849	98.48	0	0	0	0	0.044	1.52	1.52	0.008	0.71
		40	800	2.913	2.871	98.56	0	0	0	0	0.042	1.44	1.44	0.008	0.59
		36	900	2.917	2.867	98.29	0	0	0	0	0.050	1.71	1.71	0.010	0.62
		32	1000	2.916	2.744	94.10	0.094	3.22	0.023	0.79	0.055	1.89	5.90	0.033	1.93
(2) 800 to 3,000 μm	1.60	156	600	8.822	8.754	99.23	0	0	0	0	0.068	0.77	0.77	0.013	1.27
		134	700	8.644	8.553	98.95	0	0	0	0	0.091	1.05	1.05	0.017	1.46
		117	800	8.93	8.837	98.96	0	0	0	0	0.093	1.04	1.04	0.018	1.31
		104	900	9.023	8.907	98.68	0.007	0.078	0	0	0.112	1.24	1.32	0.023	1.48
		94	1000	8.938	7.216	80.73	1.337	14.96	0.227	2.54	0.158	1.768	19.27	0.331	19.33
(3) 800 to 3,000 μm	2.57	250	600	13.741	13.655	99.37	0	0	0	0	0.086	0.63	0.63	0.017	1.61
		215	700	13.753	13.655	99.29	0	0	0	0	0.098	0.71	0.71	0.019	1.57
		188	800	13.637	13.523	99.16	0	0	0	0	0.114	0.84	0.84	0.022	1.60
		167	900	13.699	13.393	97.77	0.168	1.23	0	0	0.138	1.00	2.33	0.059	3.82
		150	1000	13.700	10.618	77.50	2.568	18.75	0.359	2.62	0.155	1.13	22.50	0.592	34.60
(4) 30 μm	0.075*	* 7.3	600	0.419	0.328	78.28	0	0	0	0	0.091	21.72	21.72	0.017	1.70
		6.2	700	0.383	0.275	71.80	0	0	0	0	0.108	28.20	28.20	0.021	1.73
		5.4	800	0.407	0.282	69.29	0	0	0	0	0.125	30.71	30.71	0.024	1.75
		4.8	900	0.382	0.293	76.70	0	0	0	0	0.089	23.30	23.30	0.017	1.11
		4.4	1000	0.399	0.299	74.94	0	0	0	0	0.100	25.06	25.06	0.019	1.12

*Revised 1/4/94.

SUMMARY OF MIST ELIMINATOR CARRYOVER TEST RESULTS AS A FUNCTION OF GAS VELOCITY, LIQUID LOADING, AND DROPLET SIZE

Total Carryover = $Q_{CO} = Q_{T2} + Q_{ME} + Q_{EVAP}$

Total Liquid Load = $Q_{TOT} = Q_{T1} + Q_{CO}$

TEST MODULE IS: **Koch 2 Pass Module** A-800
1.8" Space
A_{face} = 5.20 ft^2

Test Number and Drop Size	Approximate Inlet Loading		Vg ME Face Velocity (fpm)	Q_{TOT} Total Liquid Load (gpm)	Q_{T1} Below ME		Q_{T2} Ledge Above ME		Q_{ME} Lab Mist Eliminator		Q_{Evap}		$\frac{Q_{CO}}{Q_{TOT}}$ x 100 %	Carryover Amount	
	$\frac{gpm}{ft^2}$	$\frac{grains}{ft^3}$			gpm	% Q_{TOT}	gpm	% Q_{TOT}	gpm	% Q_{TOT}	gpm	% Q_{TOT}		$\frac{gpm}{ft^2}$	$\frac{grains}{ft^3}$
(1) 800 to 3,000 µm	0.55	53	600	2.927	2.839	97.00	0	0	0	0	0.088	3.00	3.00	0.017	1.66
		46	700	2.928	2.831	96.69	0	0	0	0	0.097	3.31	3.31	0.019	1.59
		40	800	2.909	2.791	95.94	0	0	0	0	0.118	4.06	4.06	0.023	1.68
		36	900	2.953	2.801	94.85	0	0	0	0	0.143	4.84	4.84	0.028	1.82
	* →	32	1000	2.916	2.771	94.96	0.020	0.69	0	0	0.127	4.35	5.04	0.0283	1.65
(2) 800 to 3,000 µm	1.60	156	600	8.741	8.646	98.91	0	0	0	0	0.095	1.09	1.09	0.018	1.78
		134	700	8.741	8.646	98.91	0	0	0	0	0.095	1.09	1.09	0.018	1.53
	* →	117	800	8.774	8.659	98.69	0.022	0.25	0	0	0.093	1.06	1.31	0.022	1.62
		104	900	8.710	8.540	98.05	0.057	0.654	0	0	0.113	1.23	1.95	0.033	2.12
		94	1000	8.887	7.417	83.46	1.305	14.68	0	0	0.165	1.86	16.54	0.283	16.5
(3) 800 to 3,000 µm	2.57	250	600	13.829	13.756	99.47	0	0	0	0	0.073	0.528	0.528	0.014	1.37
		215	700	13.746	13.655	99.34	0	0	0	0	0.091	0.662	0.662	0.018	1.46
		188	800	13.864	13.756	99.22	0	0	0	0	0.108	0.779	0.779	0.021	1.52
		167	900	14.074	13.824	98.22	0.111	0.789	0.010	0.071	0.129	1.917	1.78	0.048	3.12
		150	1000	14.004	10.381	74.13	3.233	23.09	0.233	1.66	0.157	1.12	25.87	0.697	40.75
(4) 30 µm *Added	0.078	7.56	600	0.373	0.263	70.50	0	0	0	0	0.110	29.50	29.50	0.021	2.06
		6.48	700	0.360	0.248	68.89	0	0	0	0	0.112	31.11	31.11	0.022	1.78
		5.64	800	0.425	0.278	65.41	0	0	0	0	0.147	34.59	34.59	0.028	2.03
		5.04	900	0.399	0.277	69.42	0	0	0	0	0.122	30.58	30.58	0.024	1.56
		4.56	1000	0.420	0.266	63.33	0	0	0	0	0.154	36.67	36.67	0.030	1.75

*Revised 1/4/94.

Section 4

COMPARISON OF TEST RESULTS

4.1 Comparison of the Five Test Modules

The pressure loss, breakthrough, and liquid carryover test results are compared on Table 4-1 and Figures 4-1 through 4-8.

4.1.1 Pressure Loss Comparison

Table 4-1 in the left side data column compares the pressure loss for the five modules at 800 fpm inlet face gas velocity and 0.55 gpm/ft^2 inlet face liquid loading. This comparison shows the existing field design to have the highest pressure loss by a significant amount followed by the Munters T-271 module which has about 67% of the field module pressure loss. The other three modules are grouped between 17% and 25% of the field ME pressure loss which is significantly lower.

Figures 4-1 through 4-4 show the variation of ME pressure loss versus inlet face gas velocity. Each curve is for a different ME inlet liquid loading from dry to 1.6 gpm/ft^2. For the dry test condition (Figure 4-1), the pressure loss varies approximately as the square of the velocity. As the inlet liquid loading increases from dry to 1.6 gpm/ft^2, the pressure loss for all mist eliminators increases more rapidly as gas velocity increases than for the dry test. This is due to the liquid behavior inside the mist eliminator passages and the way the liquid interacts with the gas flow. The Munters T-272 and the two Koch mist eliminator modules are affected very little by liquid loading until reaching the 900 to 1000 fpm gas velocities where liquid carryover is measurable. The Munters T-271 module shows the most change due to the liquid loading. In a dry condition (Figure 4-1), the T-271 module compares more closely to the three low pressure loss modules. As liquid loading increases the T-271 module pressure loss shifts upward and becomes more comparable to the existing field ME pressure loss (Figures 4-3 and 4-4).

4.1.2 Breakthrough Velocity Comparison

Table 4-1 shows a general comparison of breakthrough velocity between the five modules but additional information is shown on the carryover plots for the individual mist eliminators (see key Table 3-1 for a specific figure number). As discussed in Section 3, the breakthrough reentrainment mostly occurs at the last blade bend before discharge from the ME module.

The existing field geometry module shows a breakthrough velocity range of 650 to 700 fpm for all four tests of inlet loading and inlet drop size.

The Munters T-271 module shows a breakthrough velocity range of 700 to 800 fpm for large droplet inlet liquid loadings above 0.55 gpm/ft^2. For the fine aerosol test (30 micron droplets, 0.07 gpm/ft^2), the breakthrough velocity is in the range of 850-900 fpm.

The Munters T-272 module shows a breakthrough velocity range of 600 to 700 fpm for all inlet liquid loadings and droplet sizes.

The Koch 4 Pass Module (V111-3-1.5 or B-800) shows a breakthrough velocity range of 800-900 fpm for Tests 1, 2, and 3 with large droplet inlet loading greater than 0.55 gpm/ft^2. For Test 4 with an inlet loading of 0.075 gpm/ft^2 and 30 micron droplets, there was no detected breakthrough of large droplets.

The Koch 2 Pass Module (A-800) shows the following breakthrough velocity results:

- The 600 to 800 fpm velocity range shows small size droplet carryover originating from the last blade bend which has slightly rounded corners for Tests 1, 2, and 3 with inlet liquid loading above 0.55 gpm/ft^2.
- The 800 to 900 fpm range shows large size droplet carryover like the Koch 4 Pass (B-800) module.
- For Test 4 with an inlet loading of 0.078 gpm/ft^2 and 30 microns, there is no detected breakthrough of large droplets.

4.1.3 Liquid Carryover Comparison

Table 4-1 and Figures 4-5 through 4-8 show comparisons of liquid carryover for the five modules at liquid loadings of 0.55 gpm/ft^2 (Test 1) and 1.6 gpm/ft^2 (Test 2). The liquid carryover results are shown in two units for each inlet loading: % carryover (Figures 4-5 and 4-7) and gpm/ft^2 (Figures 4-6 and 4-8). Liquid carryover results for all four inlet liquid loadings and five modules were discussed in Section 3. Figure numbers of individual module plots of liquid carryover results are identified on key Table 3-1.

On all four figures and on Table 4-1, the existing field mist eliminator module shows the highest liquid carryover starting at 600 fpm and progressively increasing as inlet face gas velocity increases.

The Munters T-272 module and the two Koch modules are all grouped on the low side of the liquid carryover curves over the range of velocity from 600 to 1000 fpm. The two Koch modules both have slightly less liquid carryover than the Munters T-272 module.

The Munters T-271 module is equal in liquid carryover performance to the three lowest carryover modules up to 800 fpm inlet face gas velocity. However, at 900 and 1000 fpm, the Munters T-271 module produces significantly more liquid carryover at inlet liquid loadings above 0.55 gpm/ft^2.

4.2 Comparison of DynaGen Data to EPRI/NELS Data

4.2.1 Comparison of Mist Eliminator Test Rigs

The DynaGen test rig described in Section 2 of this report is an open loop test system (see Figure 2-1) that draws unsaturated air from the laboratory through the mist eliminator test module and test system. It was designed to determine breakthrough velocity by observation and to measure the amount of liquid carryover at velocities above breakthrough velocity.

The EPRI test rig is a closed loop system that uses saturated air flow.

4.2.2 Affect of Using Unsaturated Air Flow

The amount of evaporation inside the test rig represents all of the liquid carryover at gas velocities below the breakthrough velocity and a significant percentage of the liquid carryover at velocities close to but above the breakthrough velocity. The DynaGen test instrumentation quantifies the amount of liquid lost by evaporation by measuring the wet bulb and dry bulb temperatures of both the open test loop inlet and outlet air flows and calculating the amount of evaporation. This quantity is listed separately for each test on the tables of test data.

4.2.3 Minimum Carryover Measurement

The minimum measurement shown on the curves for the EPRI system was about 0.00013 gpm/ft^2. They have stated in their paper that any point plotted at 0.0001 gpm/ft^2 shows no measurable carryover.

The minimum measurement shown on our tables of data for a liquid carryover excluding evaporation is 0.002 gpm or about 0.0004 gpm/ft^2.

4.2.4 Comparison of Tests for the Koch V111-3-1.5 Single Module Test

This exact same module, as best we can tell, was tested in both the EPRI and DynaGen test systems. The comparison of data is shown on Figure 4-9 taken from the EPRI/NELS 1992 paper Figure 7 with DynaGen data superimposed. Below breakthrough velocity of about 14 fps, the results presented for the DynaGen system represent only evaporation and are about 100 times larger than the very small EPRI results. Above the breakthrough velocity, the measured DynaGen results for total carryover including evaporation loss correspond very closely to the EPRI results. This Koch mist eliminator, in general, creates reentrained droplets that are smaller than the Munters T-271 and T-272 modules as determined visually. These can be compared on the video.

4.2.5 Comparison of Tests for the T-272 Munters Single Module Tests

The T-272 modules tested in the two facilities are very similar but do differ in at least one dimension: the vertical straight outlet height. DynaGen's module is 0.75" high EPRI's module is about 2.00" high. This extra height probably includes one Vee drain on the extended height.

The comparison of the data is shown on Figure 4-10 taken from the EPRI/NELS 1992 paper Figure 7 with DynaGen data superimposed. This data does not match as well until the third level of DynaGen data: carryover to the laboratory mist eliminator, where the DynaGen data is lower. The possible reasons we can see for this difference are:

(a) The DynaGen test rig has an open trough around the mist eliminator module which collects the large droplets as they work their way to the sides of the test module. These droplets are counted as total carryover in the Q_{T2} component on the test data tables. The EPRI test system may allow most of these large droplets to drain down the walls and back through the ME passages because there test section size appears to be the same cross-section size as the ME module. However, this difference did not affect the Koch module comparison (4.2.4) where including the Q_{T2} component results in a good match. The Koch module tends to create smaller drop sizes at the ME discharge.

(b) The test modules are not the same dimension for the vertical discharge of the module. The EPRI/NELS paper says this should not make a difference for either the T-271 or the T-272 modules.

(c) The DynaGen T-271 and T-272 modules may not have been cleaned enough to remove the manufacturing resins. We did soak all of our test modules in a 0.2 molar solution of sulfuric acid for 2 hours. The surface of the test modules did not feel as though resin was still present on the surface but it may not be easily detectable.

Figure 4-1

COMPARISON OF PRESSURE LOSS FOR THE MIST ELIMINATOR MODULES
AS A FUNCTION OF GAS VELOCITY AND LIQUID LOADING

Mist Eliminator Modules

- ⊙ Existing Plant - 4 Pass Chevron
- ⊡ Munters T-271 Narrow Space
- △ Munters T-272 Wide Space
- ▽ Koch 4 Pass
- × Koch 2 Pass

Notes:

(1) Test gas density is 0.076 lb/ft^3 $\pm$ 2%.
(2) Pressure loss accuracy $\pm$ 0.02 inches of water.
(3) Face velocity accuracy $\pm$ 2%.
(4) Test DRY, O gpm/ft^2

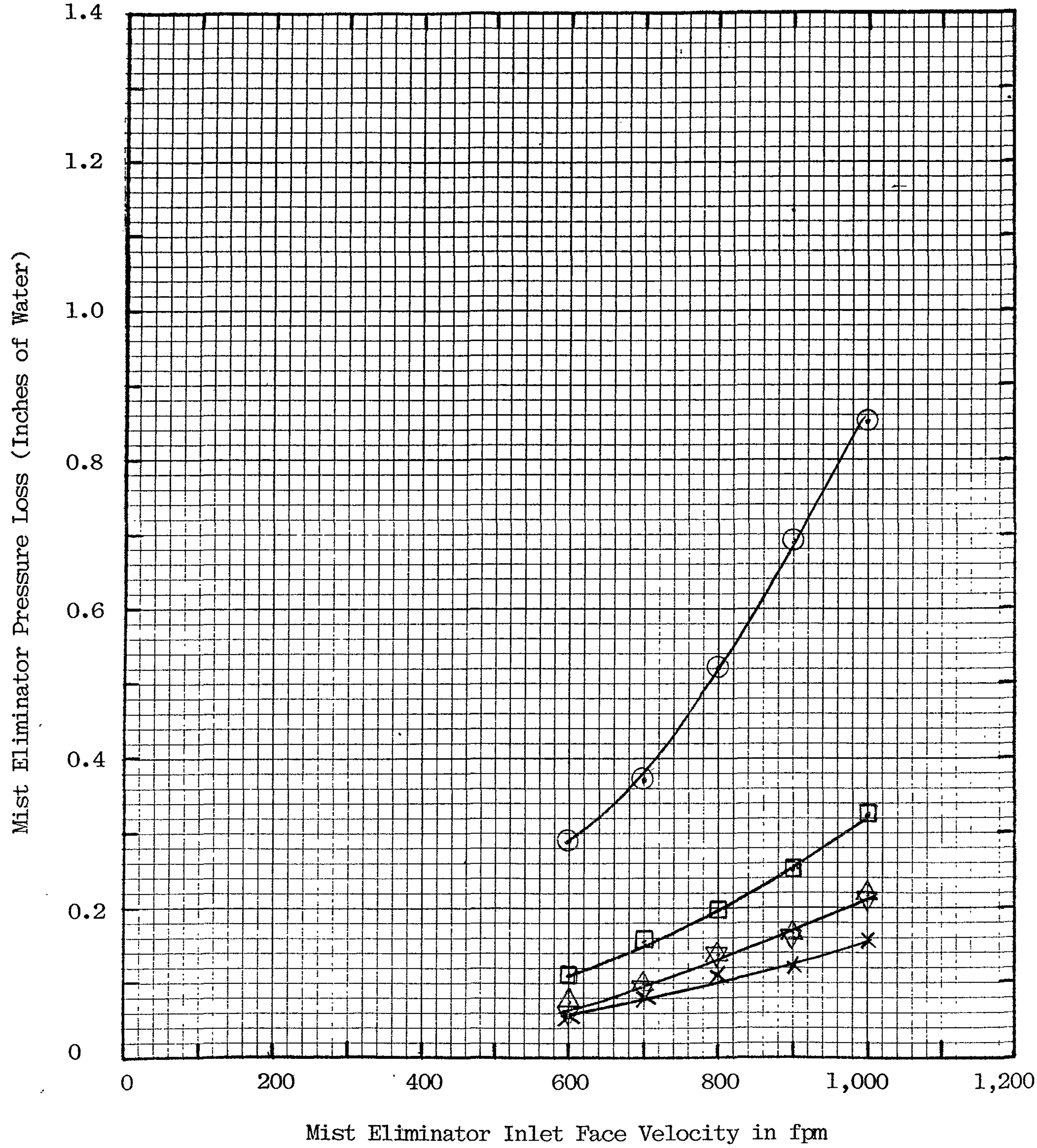


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Figure 4-2

COMPARISON OF PRESSURE LOSS FOR THE MIST ELIMINATOR MODULES
AS A FUNCTION OF GAS VELOCITY AND LIQUID LOADING

<u>Mist Eliminator Modules</u>

- ⊙ Existing Plant - 4 Pass Chevron
- ⊡ Munters T-271 Narrow Space
- △ Munters T-272 Wide Space
- ▽ Koch 4 Pass
- X Koch 2 Pass

<u>Notes:</u>

(1) Test gas density is 0.076 lb/ft^3 ± 2%.
(2) Pressure loss accuracy ± 0.02 inches of water.
(3) Face velocity accuracy ± 2%.
(4) Test 4, 0.07 gpm/ft^2

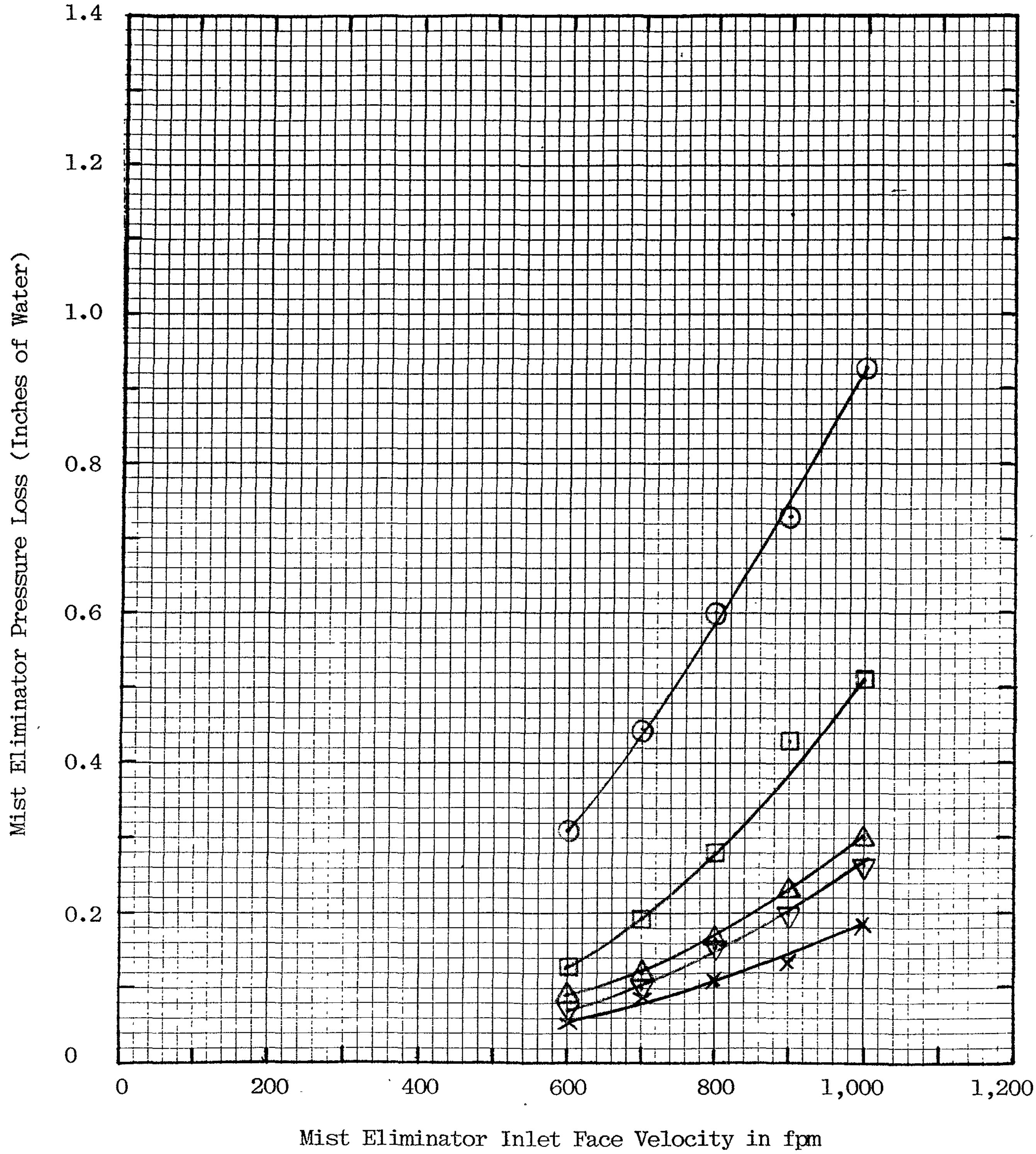

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Figure 4-3

COMPARISON OF PRESSURE LOSS FOR THE MIST ELIMINATOR MODULES AS A FUNCTION OF GAS VELOCITY AND LIQUID LOADING

<u>Mist Eliminator Modules</u>

- ⊙ Existing Plant - 4 Pass Chevron
- ⊡ Munters T-271 Narrow Space
- △ Munters T-272 Wide Space
- ▽ Koch 4 Pass
- X Koch 2 Pass

<u>Notes:</u>

(1) Test gas density is 0.076 lb/ft^3 ± 2%.
(2) Pressure loss accuracy ± 0.02 inches of water.
(3) Face velocity accuracy ± 2%.
(4) Test _1_, _0.55_ gpm/ft^2

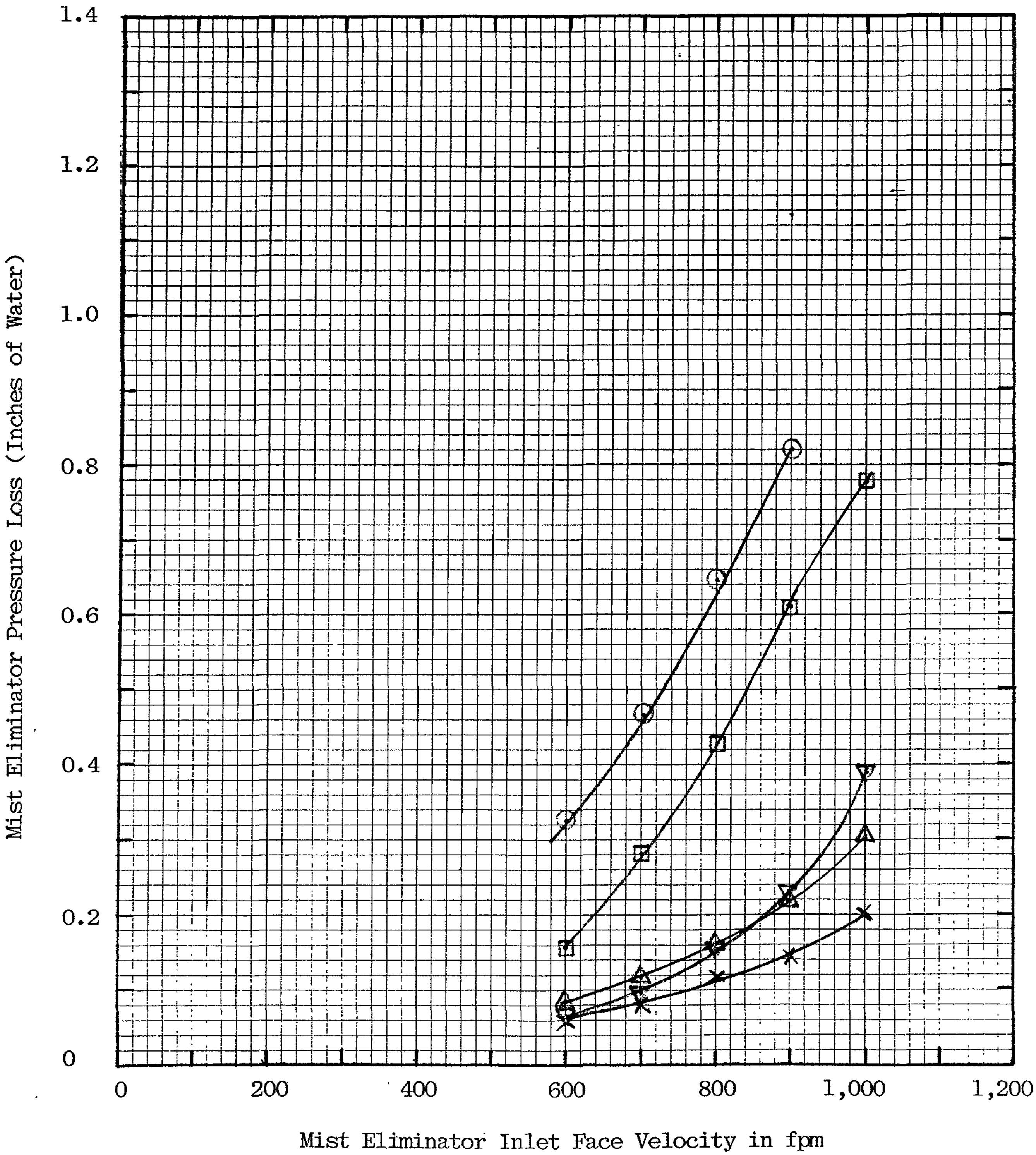

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Figure 4-4

COMPARISON OF PRESSURE LOSS FOR THE MIST ELIMINATOR MODULES
AS A FUNCTION OF GAS VELOCITY AND LIQUID LOADING

Mist Eliminator Modules

- ⊙ Existing Plant - 4 Pass Chevron
- ⊡ Munters T-271 Narrow Space
- △ Munters T-272 Wide Space
- ▽ Koch 4 Pass
- × Koch 2 Pass

Notes:

(1) Test gas density is 0.076 lb/ft^3 $\pm$ 2%.
(2) Pressure loss accuracy $\pm$ 0.02 inches of water.
(3) Face velocity accuracy $\pm$ 2%.
(4) Test 2, 1.6 gpm/ft^2

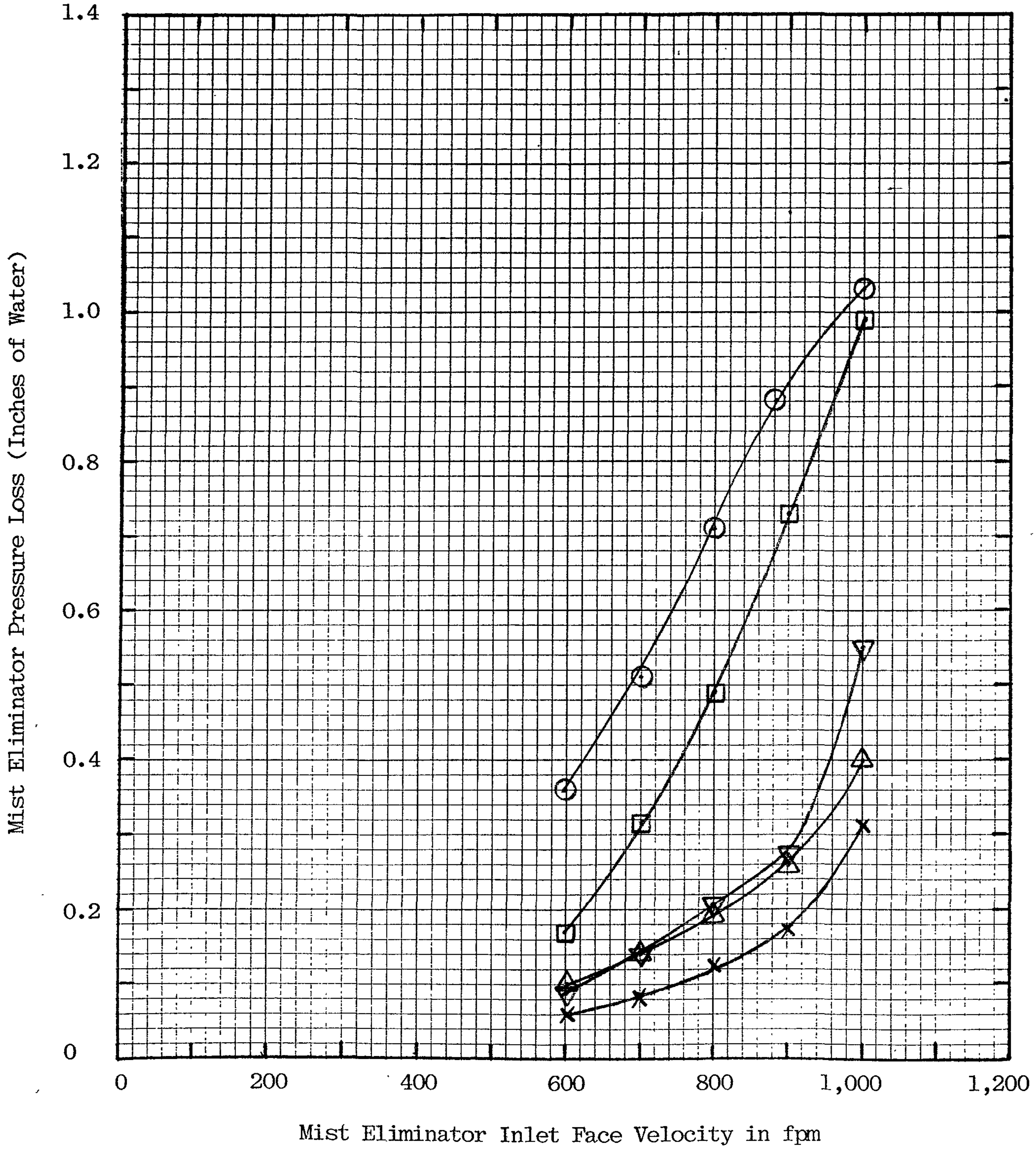

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Figure 4-5

COMPARISON OF LIQUID CARRYOVER (%) FOR THE MIST ELIMINATOR MODULES AS A FUNCTION OF GAS VELOCITY, LIQUID LOADING, AND DROPLET SIZE

Mist Eliminator Modules

- ⊙ Existing Plant - 4 Pass Chevron
- ⊡ Munters T-271 Narrow Space
- △ Munters T-272 Wide Space
- ▽ Koch 4 Pass
- X Koch 2 Pass

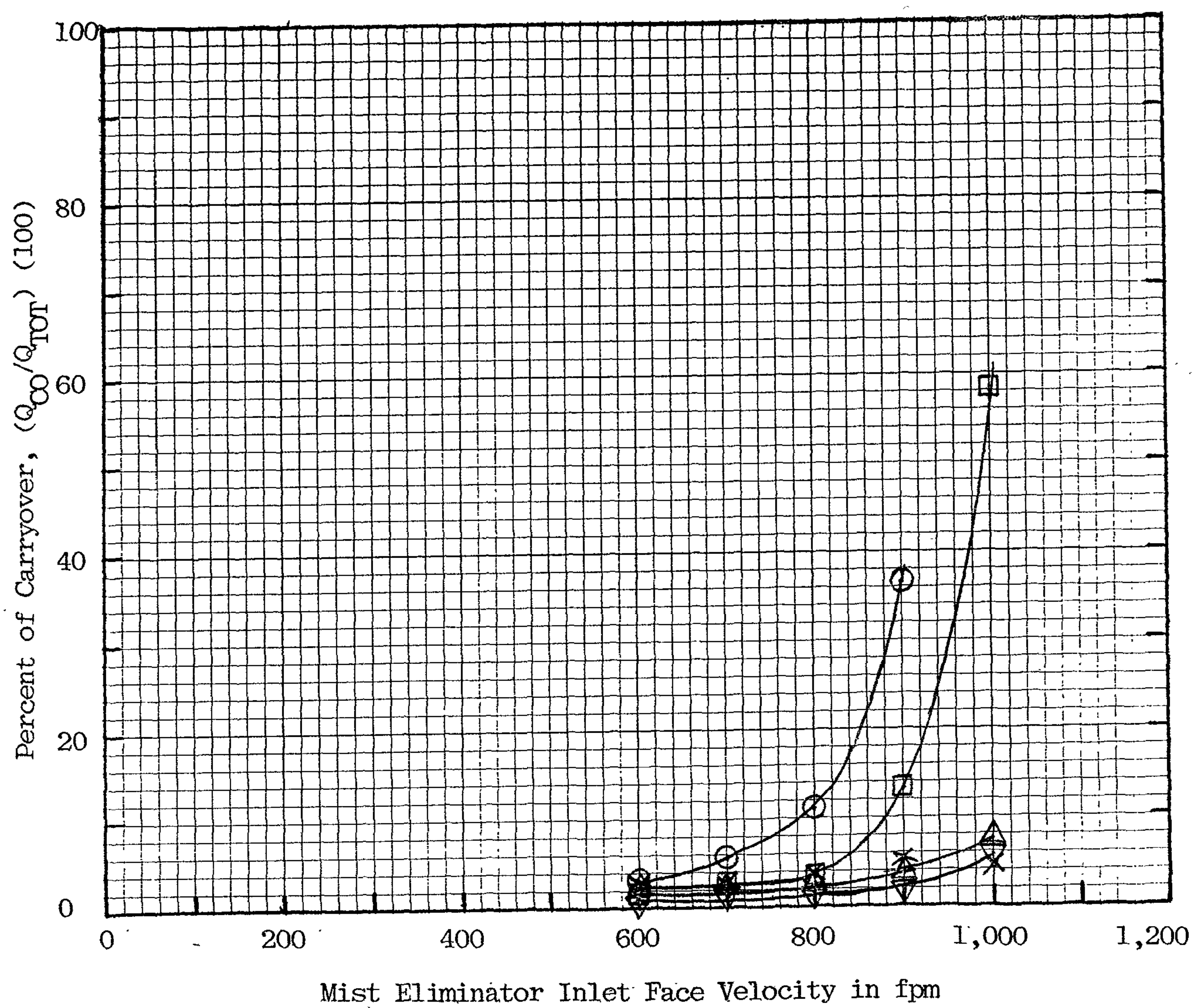
Notes:

(1) Test gas density is 0.076 lb/ft³ ± 2%.

(2) Face velocity accuracy ± 2%.

(3) Carryover accuracy ± 3.0% for Tests 1, 2, 3, and ± 10% for Test 4.

(4) Test 1, 0.55 gpm/ft²



Velocity Ranges for Start of Large Droplet Carryover

IP7_039293

Figure 4-6

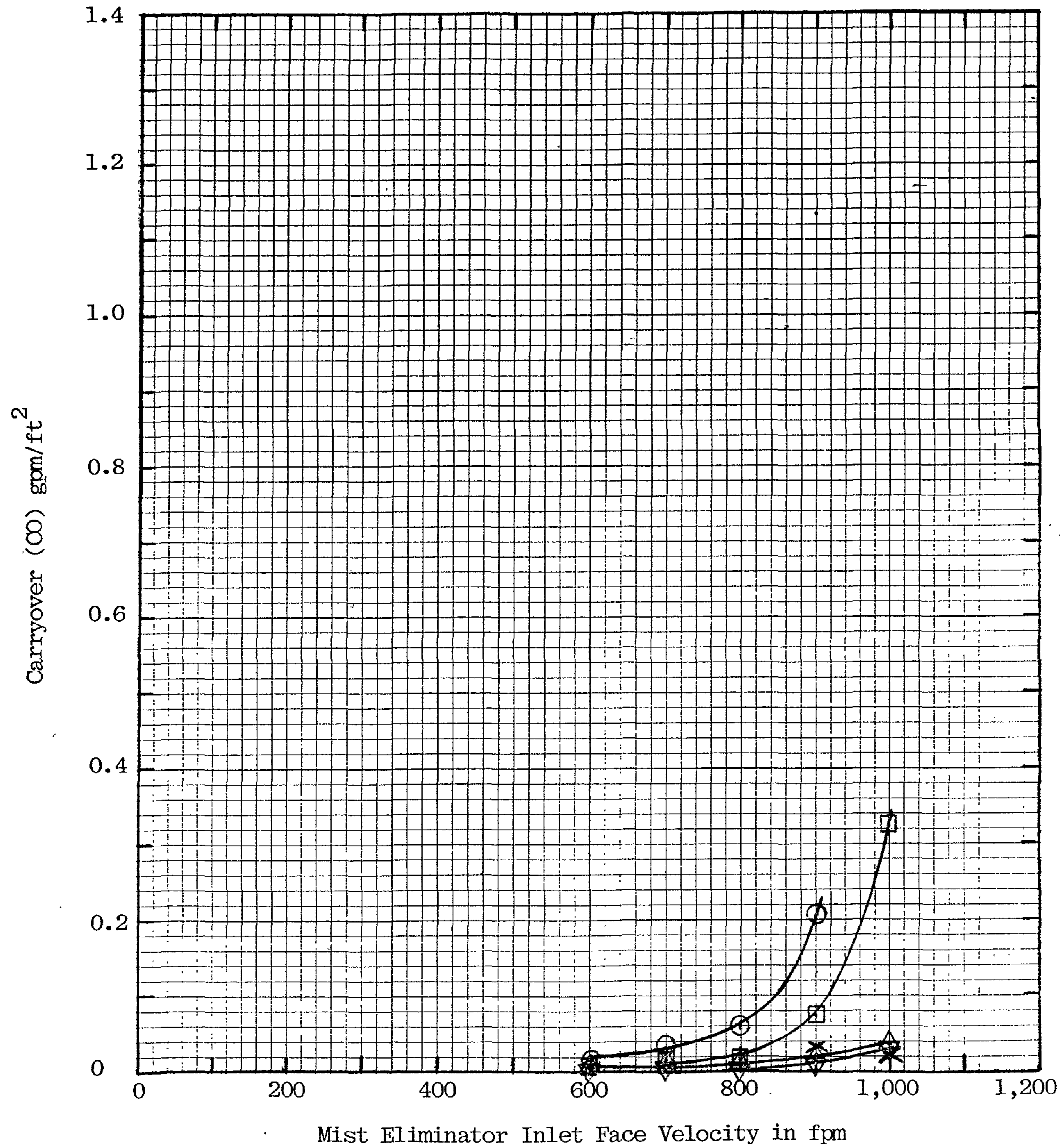
COMPARISON OF LIQUID CARRYOVER (gpm/ft^2) FOR THE MIST ELIMINATOR MODULES AS A FUNCTION OF GAS VELOCITY, LIQUID LOADING, AND DROPLET SIZE

Mist Eliminator Modules

- ⊙ Existing Plant - 4 Pass Chevron
- ⊡ Munters T-271 Narrow Space
- △ Munters T-272 Wide Space
- ▽ Koch 4 Pass
- × Koch 2 Pass

Notes:

(1) Test gas density is 0.076 lb/ft^3 ± 2%.
(2) Face velocity accuracy ± 2%.
(3) Carryover accuracy ± 3% for Tests 1, 2, 3, and ± 10% for Test 4.
(4) Test 1, 0.55 gpm/ft^2



Velocity Ranges for Start of Large Droplet Carryover

IP7_039294

Figure 4-7

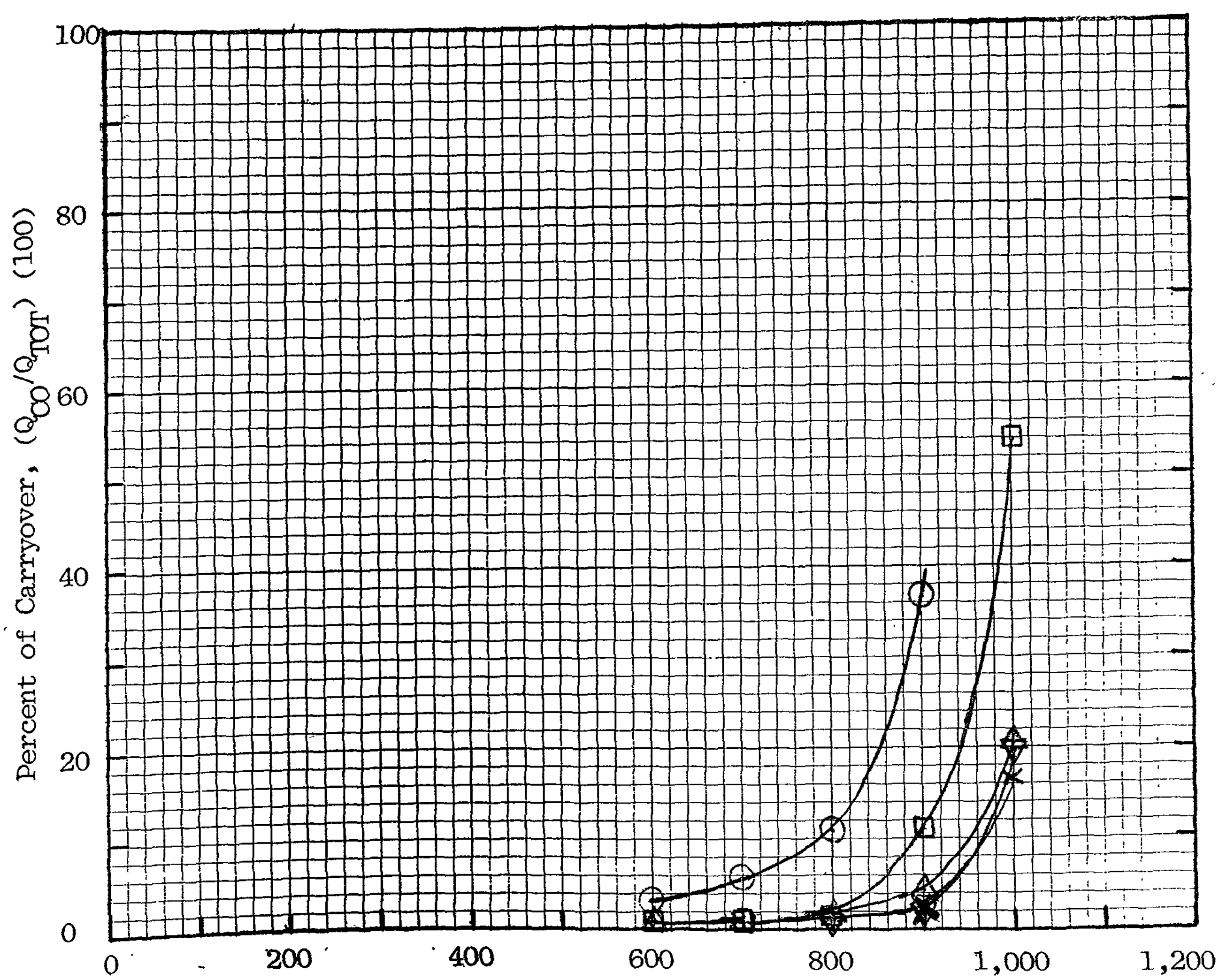
COMPARISON OF LIQUID CARRYOVER (%) FOR THE MIST ELIMINATOR MODULES AS A FUNCTION OF GAS VELOCITY, LIQUID LOADING, AND DROPLET SIZE

Mist Eliminator Modules

- ⊙ Existing Plant - 4 Pass Chevron
- ⊡ Munters T-271 Narrow Space
- △ Munters T-272 Wide Space
- ▽ Koch 4 Pass
- X Koch 2 Pass

Notes:

(1) Test gas density is 0.076 lb/ft^3 $\pm$ 2%.
(2) Face velocity accuracy $\pm$ 2%.
(3) Carryover accuracy $\pm$ 3.0% for Tests 1, 2, 3, and $\pm$ 10% for Test 4.
(4) Test 2, 1.6 gpm/ft^2



Velocity Ranges for Start of Large Droplet Carryover

Figure 4-8

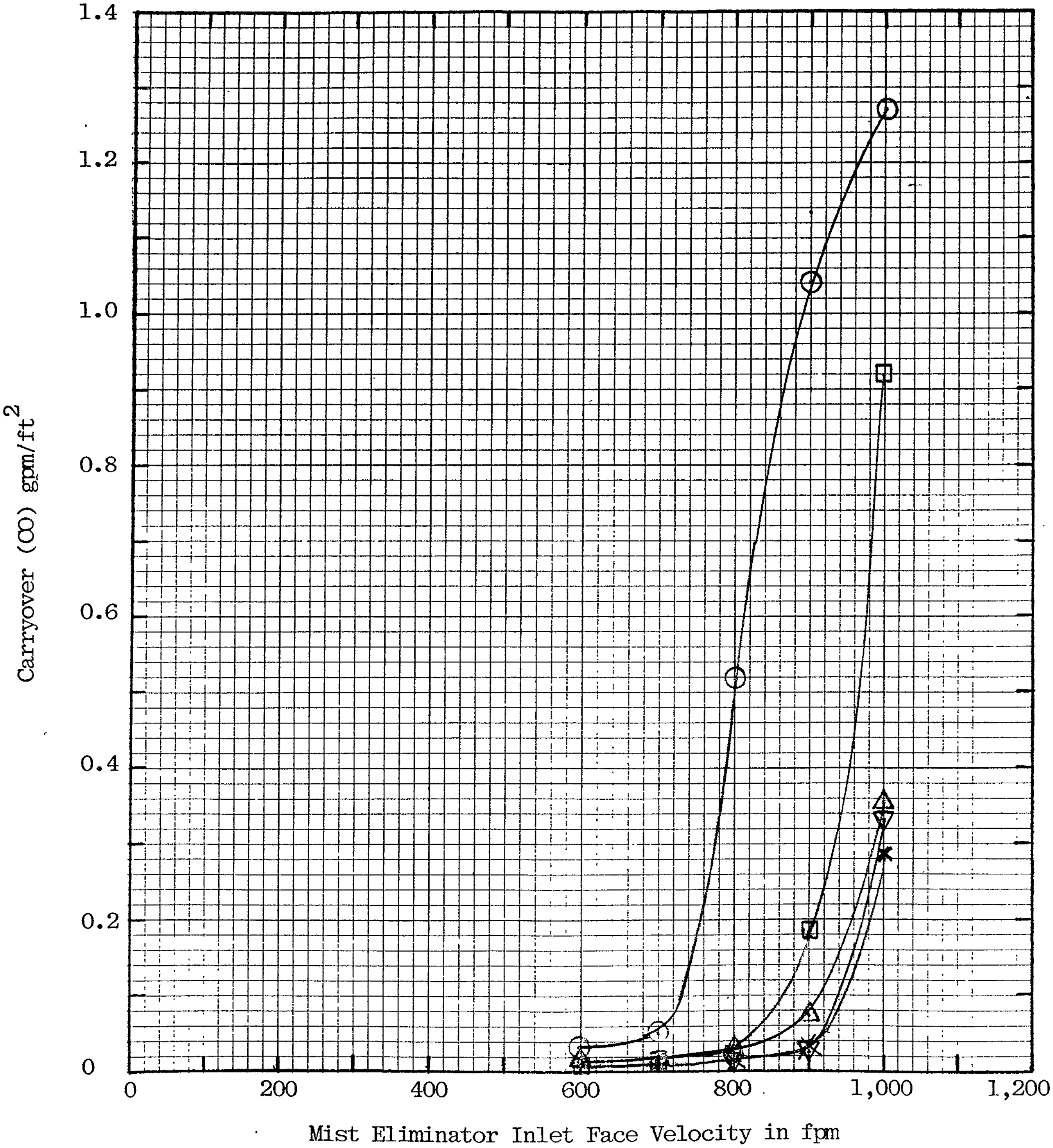
COMPARISON OF LIQUID CARRYOVER (gpm/ft²) FOR THE MIST ELIMINATOR MODULES AS A FUNCTION OF GAS VELOCITY, LIQUID LOADING, AND DROPLET SIZE

Mist Eliminator Modules

- ⊙ Existing Plant - 4 Pass Chevron
- ⊡ Munters T-271 Narrow Space
- △ Munters T-272 Wide Space
- ▽ Koch 4 Pass
- × Koch 2 Pass

Notes:

(1) Test gas density is 0.076 lb/ft³ ± 2%.
(2) Face velocity accuracy ± 2%.
(3) Carryover accuracy ± 3% for Tests 1, 2, 3, and ± 10% for Test 4.
(4) Test 2, 1.6 gpm/ft²



Velocity Ranges for Start of Large Droplet Carryover

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Figure 4-9 Carryover Results at 1.5 gpm/ft² Mist Loading for the Single-Stage, Vertical-Flow ME Systems EPRI/NELS Test Rig- Koch VIII-3-1.5

DynaGen Data for Koch V111-3-1.5 at 1.60 gpm/ft²
-- Total Carryover With Evaporation ($Q_{T2} + Q_{ME} + Q_{EVAP}$)
-- Carryover Without Evaporation ($Q_{T2} + Q_{ME}$)
-- Carryover to Lab ME (Q_{ME})

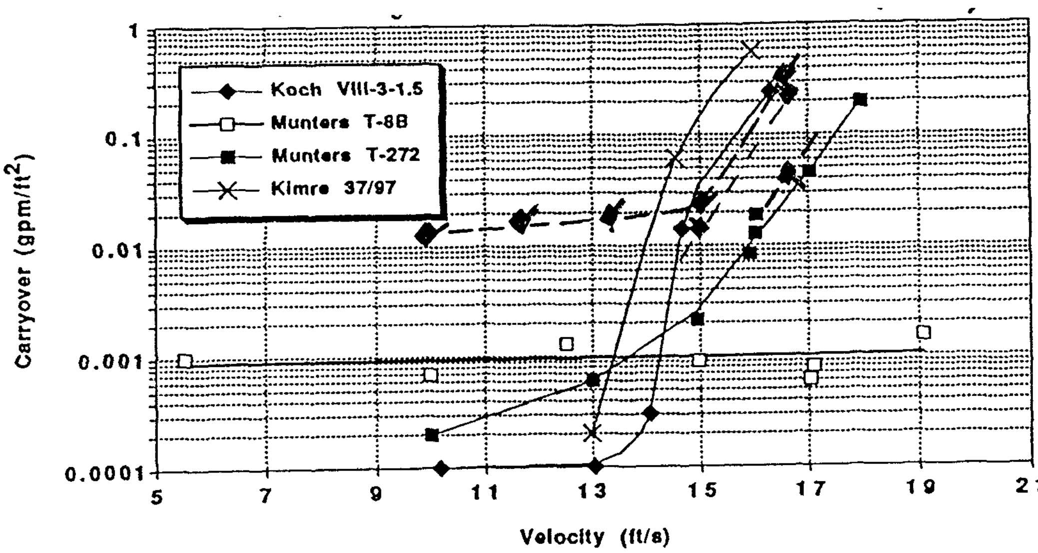

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Figure 4-10 Carryover Results at 1.5 gpm/ft² Mist Loading for the Single-Stage, Vertical-Flow ME Systems EPRI/NELS Test Rig – Munters T-272

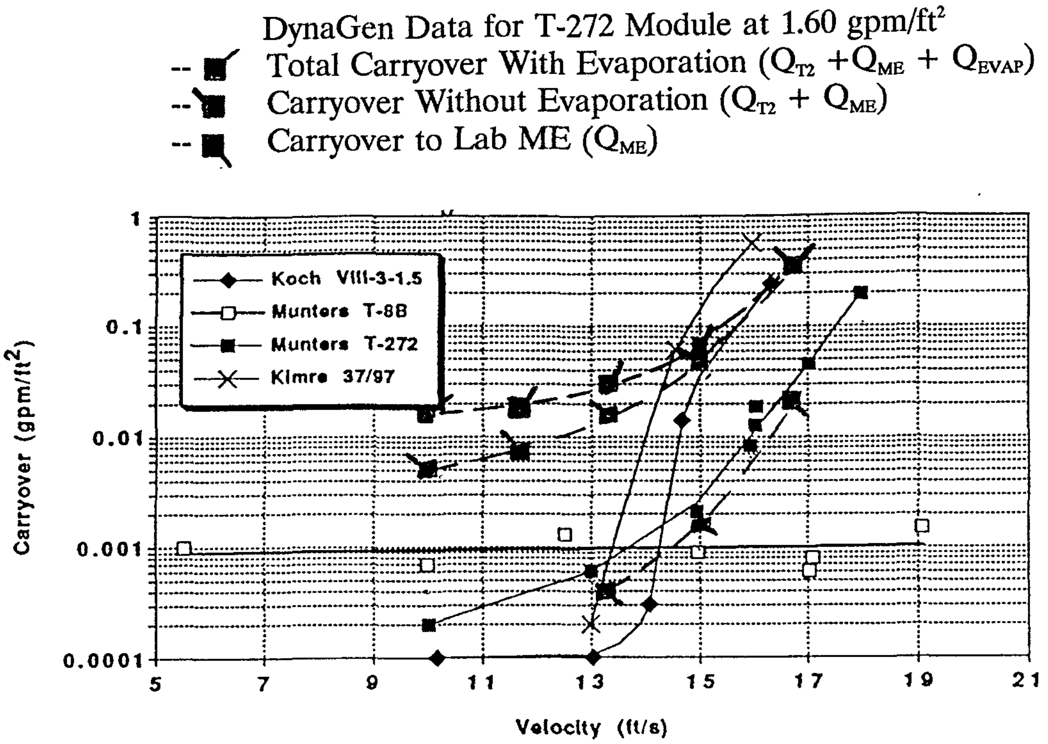

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Table 4-1

SUMMARY OF RESULTS FOR THE FIVE MIST ELIMINATOR TEST MODULES

Mist Eliminator Module	Pressure Loss Comparison at 800 fpm and 0.55 gpm/ft^2 Inlet Loading (inches of water)	Breakthrough Velocity Range (fpm)	Liquid Carryover (gpm/ft^2) at 0.55 gpm/ft^2 Inlet Loading			Liquid Carryover (gpm/ft^2) at 1.6 gpm/ft^2 Inlet Loading		
			700 fpm	800 fpm	900 fpm	700 fpm	800 fpm	900 fpm
Existing Plant 4 Pass Chevron	0.64"	650-700	0.031	0.059	0.203	0.050	0.518	1.04
Munters T-271	0.43"	700-800	0.013 Evap.	0.017 Evap.	0.072	0.013 Evap.	0.022	0.185
Munters T-272	0.16"	600-700	0.018 Evap.	0.015 Evap.	0.020	0.019	0.030	0.071
Koch 4 Pass B-800 V111-3-1.5	0.15"	800-900	0.008 Evap.	0.008 Evap.	0.010 Evap.	0.017 Evap.	0.018 Evap.	0.023
Koch 2 Pass A-800	0.11"	600-800 (small droplets) 800-900 (large droplets)	0.019 Evap.	0.023 Evap.	0.028 Evap.	0.018 Evap.	0.022	0.033

Notes: "Evap." in the carryover columns means that all of the carryover value listed is due to evaporation in the mist eliminator test system.

Section 5

CONCLUSIONS

(1) The existing field mist eliminator modules are significantly worse than any of the four other modules tested showing higher pressure loss, higher liquid carryover, and lower breakthrough velocities.

(2) The five mist eliminator modules tested rank in the following order for pressure loss from highest (worst) to lowest (best):

- Existing Field Module
- Munters T-271
- Munters T-272 and Koch 4 Pass (B-800) V111-3-1.5
- Koch 2 Pass (A-800)

(3) The five mist eliminator modules tested rank generally in the following order for breakthrough velocity from lowest (worst) to highest (best):

- Existing Field Module
- Munters T-272
- Munters T-271
- Koch 2 Pass (A-800)
- Koch 4 Pass (B-800) V111-3-1.5

(4) The five mist eliminator modules are more difficult to rank in a simple way according to liquid carryover:

- The existing field module is clearly the worst with the highest carryover at all inlet liquid loads and inlet gas velocities.
- At a liquid load of 0.55 gpm/ft^2, the four new modules perform about the same up to about 800 fpm.
- At a liquid load of 0.55 gpm/ft^2 and 900 fpm, the T-271 has 2 to 3 times the carryover of the other three new modules.
- At a liquid load of 1.6 gpm/ft^2, the four new modules perform about the same up to about 700 fpm although the Munters T-272 does have a small measurable carryover.

- At a liquid load of 1.6 gpm/ft^2 and inlet velocities of 800 fpm and above both Koch modules have lower liquid carryover than the two Munters modules.

(5) Considering that the two modules from each manufacturer would probably be used in pairs (lower/upper, Munters T-272/T-271, Koch 2 Pass A-800/4 Pass B-800), that both ME stages will be washed, and that local gas velocities could exceed 800 fpm, the Koch pair of modules are considered to be better than the Munters pair of modules based on the conclusions presented above.

IGS 92-20
REMOVE COMBUSTION GAS REHEAT

PHOTOGRAPHS FROM MODEL DEMONSTRATION #2

David K. Clark

January 24, 1994

MODEL CONSTRUCTED BY
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